

A thesis submitted to the faculty
“Mathematik / Naturwissenschaften / Informatik” of the
Hochschule Mittweida – University of Applied Sciences for
acquiring the degree “Master of Science” (M.Sc.) in Informatics

**CONCEPT, DESIGN AND PROTOTYPICAL IMPLEMENTATION OF A
UNIVERSAL INTERDISCIPLINARY RANKING SOFTWARE SYSTEM FOR
STANDINGS-BASED COMPETITION AREAS**

Ivaylo Belev, B.Eng.

First Supervisor: Prof. Dr.-Ing. Wilfried Schubert

Second Supervisor: Prof. Dr.-Ing. Uwe Schneider

Scientific Advisor: Assoc. Prof. Dr. Todor Todorov

August 2013

Abstract

There are a lot of people taking part in more than one competition. The competitions are also of a different kind. From local events with a small number of participants to international tournaments watched by many viewers. Naturally it becomes necessary a system to assess and compare the success in various competitions.

The existing ranking systems are usually specialized to fit their application area. More general ranking methods also exist. They can be applied to a wide spectrum of competition fields. However these ranking methods are still not universal and don't cover some important features of the competitions.

A totally new ranking system has been developed within the present master thesis. Its primary purpose is to evaluate and measure prestige gained by participants in competitions. The main contribution of the thesis consists of an original mathematical model that makes the ranking system unique.

The developed ranking system claims to be universal and interdisciplinary. It is based on the fundamental element that distinguishes the competition from the non-competition areas, namely standings that rank the participants according to their performance. The universality and the interdisciplinarity of the ranking system make available cross-disciplinary comparisons, which is usually very subjective and difficult for implementation.

The contribution of the master thesis extends beyond the theoretical area. A ranking software that fully implements this novel ranking system has been designed and developed. The software makes the practical benefits of the ranking system immediately available to potential application areas such as sports clubs and universities.

And finally, the developed ranking system offers a new viewpoint to the competitions – as a way of gaining prestige, rather than the traditional viewpoint of demonstrating mastery.

About the Author

Ivaylo Belev has gained significant amount of competition experience throughout his life. He has participated in more than 170 contests in diverse areas – chess, mathematics, **twall**[®], physics, volleyball, chemistry, programming and many others.

Among his competition achievements are: first place in the National Mathematics Olympiad for University Students (Bulgaria; technical majors group), first place in the National Physics Olympiad for University Students (Bulgaria), world champion in the exergaming discipline **twall**[®]. He is also included in two world ranking lists – the world chess rankings and the Pi World Ranking List.

Index

I. Introduction.....	8
1. Objectives of the Thesis.....	8
2. Composition of the Thesis.....	9
3. The Nature of Goals and Achievements.....	10
3.1 Motivation Theories.....	10
3.2 Success and Prestige.....	12
3.3 Benefits of Competition Participation.....	13
II. Preliminaries.....	15
1. In Search of the Best Ranking Method.....	15
1.1 Arrow's Impossibility Theorem.....	16
1.2 Advantages of Computer Ratings.....	17
1.3 Rank Aggregation.....	17
2. Diversity of Existing Rating and Ranking Methods.....	18
3. Overview of Paired Comparison Rating and Ranking Methods.....	18
4. World Sports Federations' Rating and Ranking Systems.....	21
5. The Problem of the Olympic Medals Ranking.....	23
6. The “TUGab Index” Ranking.....	25
III. Concept of the UnIdRaS Ranking System.....	26
1. Properties of UnIdRaS.....	26
1.1 Universality and Interdisciplinarity.....	26
1.2 Accumulative Type.....	26
2. UnIdRaS Prestige Rating.....	27
3. Discipline Recognition.....	28
4. Event Rank.....	29
4.1 Base Rank.....	30
4.2 Diversity Factor.....	32
4.3 Restrictions Factor.....	35
5. Success in Competition.....	36
5.1 Main Prestige.....	37
5.1.1 Quality Premium.....	39
5.1.2 Trophy Bonus.....	39
5.1.3 Team Bonus.....	40
5.2 Elite Bonus.....	41
5.2.1 Competition Performance.....	42
5.2.2 Elite Level.....	42

5.2.3 Maximal Bonus.....	43
6. Time Devaluation.....	46
7. Normalization of Competition Standings.....	48
8. Special Cases.....	51
8.1 Team Competitions.....	51
8.2 One-in-Many Competitions.....	51
8.3 Merged Tournaments and Special Prizes.....	52
8.4 Ranking of Rankings.....	52
8.5 Incomplete Data.....	53
9. Introducing Titles.....	55
IV. Design of the UnIdRaS Software.....	56
1. System Context.....	57
1.1 Purpose of the UnIdRaS Ranking Software.....	57
1.2 Users of the Ranking Software.....	57
2. Requirements.....	58
2.1 Functional Requirements.....	58
2.2 Non-Functional Requirements.....	61
2.3 Technical Requirements.....	63
3. Use Cases.....	63
4. Analytical Model.....	68
5. Development of the Software Architecture.....	69
5.1 Specification of Influencing Factors.....	69
5.1.1 Identification of Influencing Factors.....	69
5.1.2 Identification of Risks.....	72
5.1.3 Strategies for Solutions.....	72
5.2 Design and Documentation.....	74
5.2.1 Context View.....	74
5.2.2 Structural View.....	74
5.2.3 Behavioral View.....	76
5.3 Comprehensive Assessment – the ATAM Method.....	77
6. Implementation of the architecture.....	78
V. Design and Implementation of the UnIdRaS Database.....	79
1. Real and Abstract View of the Problem.....	79
2. Initial Requirements and Use Cases.....	80
2.1 Classes, Objects and Relations.....	80
2.2 Data Inconsistencies.....	82
2.3 Input Data.....	82
2.3.1 Calculation data.....	82
2.3.2 Additional Data.....	83

2.4 Output Data Use Cases.....	84
3. Initial Data Model.....	86
4. Normalization.....	89
4.1. Anomalies.....	89
4.2 First Normal Form.....	90
4.3 Second Normal Form.....	92
4.4 Third Normal Form.....	92
5. Implementation.....	93
VI. Prototypical Software Implementation.....	94
1. Data Input.....	94
1.1 Input Data Verification.....	95
1.2 Calculation of Prestige Gains.....	98
1.3 Storing Competition Data in the Database.....	102
2. Data Retrieval.....	104
2.1 Filters.....	105
2.2 Design Patterns.....	106
VII. Real Data Tests.....	107
1. twall® Challenges.....	107
1.1 Competitions.....	107
1.1.1 twall® World Championship 2009.....	107
1.1.2 twall® City Champion 2009.....	108
1.1.3 twall® World Championship 2010.....	108
1.1.4 twall® Challenge 2011.....	109
1.1.5 twall® Challenge 2012.....	109
1.2 Ranking Analysis.....	110
2. TUGab Index.....	112
Conclusion.....	114
Discussion.....	115
References.....	117

List of Abbreviations

AIOWF – Association of International Olympic Winter Sports Federations

ARISF – Association of IOC Recognized International Sports Federations

ASOIF – Association of Summer Olympic International Federations

ATP – Association of Tennis Professionals

BR – Base Rank

CP – Competition Performance

DBMS – Database Management System

DF – Diversity Factor

DR – Discipline Recognition

EB – Elite Bonus

EL – Elite Level

ER – Event Rank

FIBA – International Basketball Federation

FIDE – World Chess Federation

FINA – International Swimming Federation

FIVB – International Volleyball Federation

HDI – Human Development Index

IAAF – International Association of Athletics Federations

IMDb – Internet Movie Database

IMSA – International Mind Sports Association

IOC – International Olympic Committee

ITF – International Tennis Federation

MB – Maximal Bonus

MP – Main Prestige

PGRS – Prestige Gain Ranking System

PPG – Partial Prestige Gain

QP – Quality Premium

RF – Restrictions Factor

SC – Success in Competition

TPG – Total Prestige Gain

UPR – UnIdRaS Prestige Rating

WFCC – World Federation for Chess Composition

I. Introduction

The master thesis refers to many fields. To make it easier to follow, this introductory chapter offers an overview of the approach and the construction of the work. Also the social context of the master thesis has been described. It constitutes the background and the reason for existence of the present work.

1. Objectives of the Thesis

The challenging task of this master thesis is a universal interdisciplinary ranking system to be developed. It should be used for evaluation and measurement of prestige gained by participants in competitions. The ranking system should be designed in a way to stimulate further participation in competitions.

The ranking system should be universal and interdisciplinary. This means that all types of competition systems should be supported (e.g. knock out, round robin, Swiss system, etc.), as well as all competition areas (e.g. all kinds of sports), making cross-disciplinary comparisons possible.

The ranking system has to take into account the rank of the competition (local, national, international, etc.), as well as the competitions' strength (some competitions are stronger than others of the same rank). The popularity of the competition field should also play a role (for example, tennis is more popular than darts and thus higher appreciated, leading to higher prestige gains). The system shouldn't be limited only to individual competitions but should support team events too.

A software that fully implements the ranking system has to be developed in order to offer a practical application of the ranking system. It should support diverse statistics, so that the users of the software have the possibility to create rankings that suit their needs best.

As main target application areas of the ranking system are intended universities (evaluating the contribution of the students to the university's prestige), sport clubs (awarding the players with the biggest achievements within a given time period), municipalities (distributing funds among sport clubs according to their competition performance during the year).

2. Composition of the Thesis

This overview of the structure of the thesis gives a better idea of what is to be expected further on. A brief description of the contents of each chapter is given below.

The current chapter continues with the subject of goals and achievements, which is the area related to the present work. It deals with the motivation and the possibilities for gaining prestige as a motivation factor.

Chapter II contains an extensive literature research of the state of the art in the field of rankings. An overview of the most prominent ranking methods as well as the ranking systems in practical use has been made. This helps to distinguish the newly created ranking system from everything already existing and to show how it is better than the rest.

Chapter III is the essence of the work. It is dedicated to the concept of the new ranking system and the development of the underlying mathematical model.

In Chapter IV the architecture of the software has been designed, following a standard verified methodology.

Chapter V deals with the design and the implementation of the database which is an essential element in the ranking software.

Within Chapter VI the prototype of the ranking software has been developed. It enables the practical use of the ranking system.

In Chapter VII the results of the application of the ranking system to existing areas are discussed. The TUGab Index ranking has been recalculated and the resulting rankings have been compared to the original ones.

In the Conclusion a summary of the whole thesis and the achieved results is presented.

The Discussion gives some ideas for further improvement of the new ranking system.

The installation files, the source code and the user manuals can be found on the CD which accompanies the master thesis.

3. The Nature of Goals and Achievements

“Man is a goal seeking animal. His life only has meaning if he is reaching out and striving for his goals.”

– Aristotle

3.1 Motivation Theories

Why do people try to climb the highest mountains? Why do they want to explore the unknown? Why do people compete? Who is the fastest? Who is the strongest? Challenge. Curiosity. Recognition.

Motivation is what makes people act and what keeps them going until they reach their goals. However motivation is not a unitary phenomenon – it can have different nature and can not only vary in level, i.e. how much motivation, but also in orientation, i.e. what type of motivation (Ryan & Deci, 2000, p. 54). Many theories exist that deal with this topic.

Deci & Ryan (1985) distinguish in their Self-Determination Theory between two types of motivation: intrinsic and extrinsic. The intrinsically motivated people do a given task because of the task itself. They are usually interested, curious, and focused on it. For example, a person plays volleyball because it brings him joy and that makes him absorbed by the game while playing (i.e. entirely focused). On the other hand are people who are extrinsically motivated. They are interested in the outcomes of their actions more than the task itself. For example, a student studies because he wants to get a good grade. In life usually the people are motivated by a combination of intrinsic and extrinsic reasons – for example, a worker does his job because he likes it and gets paid for it.

Csikszentmihalyi (1998) has developed the theory of flow. When an individual's capability matches the challenge level of the task then the so-called “flow” occurs, which is a state of deep involvement associated with intrinsic motivation. We have the best motivation when the individual is working toward a personally meaningful goal and its attainment requires activity at a continuously optimal level of difficulty – a too easy task is boring and a too difficult one leads to anxiety. The state of flow is related to a number of positive emotional and mental health factors.

The expectancy-value theories of achievement motivation state that important determinants of individuals' motivation to perform different achievement tasks are their

expectancies for success and the value they have for succeeding i.e. the relative attractiveness of succeeding (or failing) on a task (Wigfield, 1994, p. 50).

Main aspect of achievement motivation is goal orientation. Elliot (1999) defined a 2 x 2 goal orientation framework based on the intersection of mastery-performance and approach-avoidance. The first dimension resembles the competence level, which can be related to either mastery or performance. The mastery standards are set to absolute criteria like earning 70% of the possible points in an exam. The performance standards are relative to other peoples' performances – for example, to become third in a competition. The second dimension of the orientation framework refers to the desire for a particular outcome, called valence. The positive valence is called *approach* and defines a strong desire for an outcome. The negative valence is known as *avoidance* and represents a strong aversion to an outcome. Intersecting the two dimensions yields four different achievement orientations: mastery approach (desire to achieve a certain absolute goal), mastery avoidance (desire to avoid failure in reaching the goal; requires that the person has gained mastery first), performance approach (desire to appear competent compared to others), and performance avoidance (desire to avoid appearing incompetent relative to others).

Hertzberg (1987) researched the motivation in the context of a job field. He defined motivation needs that are fulfilled by what he called motivator factors, such as achievement, recognition, work itself, responsibility, advancement. In this point of view we can look at motivation from a more general perspective – motivation as an urge to satisfy basic human needs.

Maslow (1943) defined five groups of such basic needs. The fourth group represents the esteem needs, which are also divided into two subsets. The first subset refers to the need for self-respect – a person may have a need for competence, mastery, independence, self-confidence. The second subset is the need for respect from others – this may include a need for appreciation, recognition, importance, attention, prestige.

The desire for gaining recognition and prestige is an extrinsic motivation factor for participation in competitions which is closely related to the subject of this master thesis. And the desire to improve and perform better in competitions has an intrinsic motivation nature.

3.2 Success and Prestige

But what is prestige? The Oxford Dictionaries¹ give an excellent definition: “Widespread respect and admiration felt for someone or something on the basis of a perception of their achievements or quality”. Even from the definition it can be seen that prestige is subjective – it depends on the people's perception.

Generally one can gain prestige by being successful. However, success is a vague concept. What can be a success for one person, may be something usual for another. Success is usually determined by a target group. If the people in the group appreciate certain results, achieving them is seen as success (by the group). In this way absurd activities and “talents”, like fastest bursting of three balloons with the back², may be meaningful as long as they bring appreciation and prestige.

Achievement motivation involves the need and drive for success. People feel satisfaction when others recognize and appreciate their accomplishments. Achievement motivation and the eventual prestige gain can be classified to the extrinsic motivation factors. In the terms of the 2 x 2 goal orientation framework (Elliot, 1999) prestige gain motivation falls under the *mastery approach* category when speaking in a general sense, and under the *performance approach* when having prestige gain from competitions in mind.

Being better than the others gains respect and prestige. The desire of being superior results in a natural aptitude for competitiveness. That is why so many competitions in different areas exist.

Within this master thesis a system for evaluation and measurement of prestige gained in diverse competition areas has been developed and used to generate rankings. The ranking system is also designed to be a motivation factor for participation in as many competitions as possible. Now follows the answer of the fundamental question: “Why is it good to take part in competitions?”

1 www.oxforddictionaries.com

2 A Guinness World Record by Julia Gunthel in 2007.

3.3 Benefits of Competition Participation

A competition is “an event or contest in which people take part in order to establish superiority or supremacy in a particular area”³. Beside the possibility of gaining prestige by defeating others, there are also other benefits.

Contests are mostly organized in two major areas – in sports and in science. Sports have competitive character and benefit from that but even without competitions the involvement in sport activities correlates with many positive developmental indicators, which are not so obvious at first glance – improved self-esteem, goal attainment, social skills, improved academic performance (Eccles et al., 2003; Richman & Shaffer, 2000).

Competitions are viewed as an important resource in education for gifted and talented students (Renzulli, 1994; Riley & Karnes, 2007 – both cited by Bicknell & Riley, 2012). They offer the students the opportunity to strive for personal achievement, which also leads to personal development. Karnes & Riley (1996 – cited by Riley, 2004) show that competitions can enhance students' self-directed learning skills, self-awareness, self-esteem and sense of autonomy. However, they state that the focus should be placed on the participation itself and not solely on the winning. Taking the risks, time, and energy involved in a contest participation indicates a winning spirit and should be considered as an accomplishment.

Competitions can be a strong motivator for students to study and work hard in order to achieve a certain goal provided by the competition. On the other hand, they could be criticized as an extrinsic motivator that could undermine intrinsic motivation. Ozturk & Debelak (2008) share the opinion that academic competitions cannot be merely extrinsic motivators, but a combination of intrinsic and extrinsic motivation at varying rates, depending on the nature of the competition, the duration of the preparation, and the age/maturity of the participants. Ozturk & Debelak (2008) give the example that if a competition involves only one gathering of students and requires almost no preparation, it will mostly have extrinsic motivation character. But if a competition demands continuous and hard work throughout a long preparation period, it is not reasonable to think that it only provides extrinsic motivation. They also emphasize that use of extrinsic motivators is unavoidable up to a certain level of maturity. Lepper et al. (2005, p. 193) state that academic competitions can help develop “internalized motivation – those originally

3 Definition by www.oxforddictionaries.com.

external motives that have over time become incorporated into one's personal goal or value systems".

Competitions can not only inspire and motivate people to succeed but also teach them how to face failure – not as a failure but as a resource to learn, improve and grow as personalities.

Competitions have many benefits and participation in them should be encouraged. One way to do so is through rankings, which give the competitors one more goal to aim at, and can act as a source of motivation.

II. Preliminaries

Today's world is characterized by flood of information, leading to an abundance of choices and alternatives. Rankings play an increasingly important role in assisting individuals and institutions in making decisions. Customers seek the best product, search engines return the most relevant pages, sport fans want to know how good their favorite sports team is.

Another aspect of deploying ratings and rankings is that by measuring performance one can distinguish success from failure, as it is often said – what gets measured, gets managed. Rankings can serve as a reference point of one's performance. In this way success can be rewarded and in case of failure, steps for improvements can be taken.

Also a reason to make rankings can just be people's inherent tendency to compare – measuring and ranking lies in the human nature. Benefits and possible dangers brought by rankings are discussed by Souba (2008).

Examples for some famous rankings are: The Top 500 Sites on the Web⁴, QS World University Rankings⁵, TOP500 Supercomputers⁶, Forbes List of Billionaires⁷, Internet Movie Database (IMDb)⁸, Human Development Index (HDI)⁹, and numerous sports rankings.

1. In Search of the Best Ranking Method

The difference between a rating and a ranking should be made clear. A precise definition is given by Langville & Meyer (2012):

*A **ranking** of items is a rank-ordered list of the items. Thus, a ranking vector is a permutation of the integers 1 through n .*

*A **rating** of items assigns a numerical score to each item. A rating list, when sorted, creates a ranking list.*

4 www.alex.com

5 www.topuniversities.com

6 www.top500.org

7 www.forbes.com/billionaires/

8 www.imdb.com/chart/top

9 hdr.undp.org/en/statistics/

The different ways to generate a ranking can be grouped in three categories:

1. Voting system where people submit their opinions.
2. Computer-generated rankings using certain algorithms.
3. Mixed – aggregation of human votes and/or several computer-generated rankings.

Some specifics regarding these three alternatives follow.

1.1 Arrow's Impossibility Theorem

In search for the perfect ranking system, we may first look at the question: “What is the perfect voting system?”, which has already been answered. In 1951 Kenneth Arrow proved his Impossibility Theorem (Til, 1978, analyzes it in details), which states that no voting system with three or more candidates can simultaneously satisfy the following four common sense criteria for an ethically acceptable system:

- Universal applicability – the system must be applicable to any possible configuration of individual orderings, i.e. every voter should be able to rank the alternatives in any arrangement of his/her choice.
- Non-dictatorship – the preferences of a single individual, irrespective of the preferences of everyone else, should not be able to determine the overall ranking.
- The weak Pareto principle – when all individuals strictly prefer alternative X to alternative Y, then in the final ranking X should be also ordered higher than Y.
- Independence of irrelevant alternatives – in the complete ranking the ordering of alternatives X and Y should be independent of the individual ordering of a third alternative Z. This means that if the voters always rank alternative X ahead of alternative Y within a subset, then this rank order should be maintained when expanding back to the set of all alternatives.

The four criteria seem obvious but the result certainly not. Arrow proved that it is impossible for any voting system (including all existing ones and those to be invented) to satisfy all four common sense criteria simultaneously. The Impossibility Theorem targets the voting systems, but we should also have realistic expectations about the ranking systems as well.

A generally best ranking system cannot exist if there is no definition of what “best” means in terms of criteria to be satisfied. There are hundreds of rating systems which are better or worse depending on what they are used for.

1.2 Advantages of Computer Ratings

Computer ratings have two big advantages compared with the human rankings. The first one is that they can process an enormous amount of data (hundreds of teams and thousands of games), and much faster than the humans. The second advantage is that every team is treated the same, i.e. the ratings are objective. This second property guarantees an objective system that plays no favorites but because of that can cause disagreement with public opinion, which in turn is strongly influenced by the media.

1.3 Rank Aggregation

If multiple ranking methods are used to create a final ranking, aggregation of the single results should be performed. Two simple methods for rank aggregation are the *average rank* and the *Borda count*.

In the average rank method the integers representing a rank in multiple rank-ordered lists are averaged to create a new list with values, which is used to determine the final ranks. Every single rank list must contain all players/teams. Table 1 illustrates the method.

Team	Some Ranking Method				Rating	Average Rank
	I.	II.	III.	IV.		
Team A	2	2	1	2	1.75	1
Team B	1	4	2	1	2.00	2
Team C	3	1	4	4	3.00	3
Team D	4	3	3	3	3.25	4

Table 1: Average Rank

Another simple method for rank aggregation is the Borda count. Table 2 shows the example above but this time using the Borda count method. The numbers listed next to the teams show how many other teams have outranked the team. By summing the rows for the four ranking methods, we get a Borda count aggregation of the four lists.

Team	Some Ranking Method				Borda Count	Borda Rank
	I.	II.	III.	IV.		
Team A	1	1	0	1	3	1
Team B	0	3	1	0	4	2
Team C	2	0	3	3	8	3
Team D	3	2	2	2	9	4

Table 2: Borda Count

2. Diversity of Existing Rating and Ranking Methods

The need for rankings in various fields has led to the development of many different ranking systems. To have an idea of the variety, we can just look at the Massey Ratings website¹⁰, where we can find 124 college football teams from the National Collegiate Athletic Association Division (USA) compared using 124 different ranking methods (as of July 15, 2013).

For creating a ranking there should be an objective and robust method to measure the performance of each competitor (or team). Simple win-loss statistics may not be enough or often misleading if the competitors/teams play under different conditions; and polls suffer from human limitations and subjectivity.

A lot of researchers have developed algorithms which operate on historical data from past competitions and generate computer ratings. These ratings objectively quantify the strength of each competitor/team based on definite criteria and are related to the winning chances of a given player/team against another. A closely connected field is analyzing historical data with betting purposes to make predictions of future competition outcomes. So it can be distinguished between predictive and earned ranking methods (Sorensen, 2000, p. 1-2). The emphasis of this master thesis is on the earned ranking methods. More on predictive ranking methods is discussed by Schumaker et al. (2010).

3. Overview of Paired Comparison Rating and Ranking Methods

Langville & Meyer's (2012) recent book is a perfect starting point for anyone interested in ratings and rankings. They present an overview of some of the most popular ranking algorithms. Some of them are briefly listed below.

¹⁰ masseyratings.com

Massey's least squares method can be summarized with the equation:

$$r_i - r_j = y_k,$$

where y_k is the margin of victory for game k , and r_i and r_j are the ratings of teams i and j . The idea is that the difference in the ratings r_i and r_j of the two teams ideally predicts the margin of victory in a contest between these two teams. The ratings for the teams are unknown, but the match data is available. An equation of this form can be constructed for every game k , thus creating a system of linear equations.

The Colley Rating Method is a modification of the rating system that uses winning percentage. Winning percentage rates team i with the value r_i according to the rule:

$$r_i = \frac{w_i}{t_i},$$

where w_i is the total number of wins of total number of games t_i played by team i .

Colley modifies the traditional winning percentage formula to get:

$$r_i = \frac{1 + w_i}{2 + t_i},$$

The Colley ratings have a conservation property. Each competitor/team begins the tournament/season with an initial rating of $\frac{1}{2}$. As the tournament/season progresses the ratings of the teams vary above and below this center point depending on the game outcomes. When one team wins, its rating increases, while another team's rating decreases. But the average of all ratings remains at $\frac{1}{2}$. The Colley method is suitable for applications in which the equivalent of point differential data is not available.

Elo's rating system was developed primarily for chess but then was adopted (eventually with some modifications) in other areas. It is based on the assumption each player's performance is a normally distributed random variable x with a mean μ that can change only slowly with the time. This means that a player might perform better or worse from one game to the next, but μ is essentially constant in the short-run, taking a long time to change. Once a rating for a player becomes established, then changing it depends on the degree to which the player is performing above or below his mean. The so-called "K-factor" aims to properly balance the deviation

between actual and expected scores against prior ratings. If K is too large, playing only a little above expectations can generate a big change in the ratings. On the other hand, if K is too small, even a significant improvement in the player's skills cannot change his rating a lot.

The Markov rating method is based on „voting“. Every game between two teams results in giving (exchanging) of votes – the losing team votes for the winning team. There can be many modifications. For example, using the margin of victory. In this case, both teams can cast votes equal to the number of points given up in the match-up. At the end, the team collected most votes earns the highest ranking.

Beside the above listed rating methods Langville & Meyer (2012) also look at the offense–defense rating method, Keener’s method, ranking by reordering methods, and user preference ratings.

Recently Barrow et al. (2013) have empirically compared 8 sports ranking methods examining their predictive power. These methods were: winning percentage, rating percentage index, least squares pairwise comparison, maximum posterior, Keener's direct method, PageRank rating, random walker, and Elo's method. The methods had two implementations – one using only win-loss data and the second using score-differential data. Part of the findings were that implementations utilizing score-differential data are usually more predictive.

González-Díaz et al. (2013) have recently published a comprehensive paper comparing the ranking methods: scores, maximum likelihood, Neustadt, fair bets, least squares, Buchholz, recursive performance, recursive Buchholz, generalized row sum. An extensive mathematical analysis of these ranking methods is made with respect to a wide set of properties – anonymity, homogeneity, symmetry, flatness preservation, order preservation, inversion, negative response to losses, score consistency, homogeneous treatment of victories, independence of irrelevant matches, positive responsiveness to the beating relation, bridge player independence, non-negative responsiveness to the beating relation, self-consistent monotonicity, and linear solvability.

All the ranking methods listed in this section are based on direct (mostly pairwise) comparison data. Although these systems are very good, they are not applicable if we want to make interdisciplinary comparisons. What other kinds of rating systems are deployed by different sports federations will be discussed next.

4. World Sports Federations' Rating and Ranking Systems

Arguably sports are the widest area where rankings are being used. According to the World Sports Encyclopedia¹¹ more than 8000 indigenous sports and sporting games exist, 3000 of them described in the encyclopedia (mind games are not considered as sports). However the sports played internationally that also have official world governing organizations are much less but still numerous. As of July 24, 2013, the International Olympic Committee (IOC) recognizes 68 international sports federations. The Association of Summer Olympic International Federations (ASOIF) has 28 of them as members, and other 7 are members of the Association of International Olympic Winter Sports Federations (AIOWF)¹². The rest 33 international federations (among them two mind sports federations – the one of chess, and the second of bridge) are members of the Association of IOC Recognized International Sports Federations (ARISF)¹³. The IOC also recognizes SportAccord¹⁴ – an umbrella organization for both Olympic and non-Olympic international sports federations as well as organizers of international sporting events. SportAccord recognizes 93 international sports federations (68 of them are those recognized by IOC), which fulfill the following five requirements¹⁵:

- *The sport proposed should include an element of competition;*
- *The sport should not rely on any element of “luck” specifically integrated into the sport;*
- *The sport should not be judged to pose an undue risk to the health and safety of its athletes or participants;*
- *The sport proposed should in no way be harmful to any living creature;*
- *The sport should not rely on equipment that is provided by a single supplier.*

Most of the sports federations have various ranking systems to determine the strength of their players/teams. The resulting sport rankings attract a lot of attention not only of the involved players but also of all the sports fans.

11 www.sportencyclopedia.com

12 Some federations are in charge of more than one sport. A list of all IOC official sports can be found at www.olympic.org/sports

13 www.arisf.org/members

14 www.sportaccord.com

15 The five criteria constitute the SportAccord's definition of sport at www.sportaccord.com/en/members/definition-of-sport

Stefani (2011) made a comprehensive study, examining the official rating systems of 159 sports¹⁶, which is of great interest for this master thesis.

He divides the sports in three categories:

- combat sports – opponents are in direct physical contact, as in boxing;
- object sports – opponents attempt to control an object, as in basketball and chess;
- independent sports – significant contact is not allowed, as in diving and biathlon.

Of 159 examined by Stefani (2011) sports, 18 are combat, 67 are object, and 74 are independent. As to the rating systems – 60 sports don't have any; 2 sports have a subjective rating system in which a group of experts rank the competitors; 84 have an accumulative system in which the competitors receive points from participation in contests; and 13 sports have an adjustive system in which a rating adjusts itself, using the difference between the real performance of the competitor and a prediction of that performance based on past results. From the summary (Stefani, 2011) in Table 3 can be noticed that every type of rating system is prevalently used in a certain type of sport.

Type	Number	Rating System			
		None	Subjective	Accumulative	Adjustive
Combat Sports	8	12	2	3	1
Independent Sports	74	18	0	53	3
Object Sports	67	30	0	28	9
Total	159	60	2	84	13

Table 3: Different types of sports rating systems

Subjective systems are used only in combat sports, where the judging in the sport may also be entirely subjective.

Objective-non-decreasing systems, i.e. accumulative systems, are mostly used by independent sports, where a weighting procedure is used to convert performance to points. These ranking systems are called accumulative because through tournament participation the competitors can only gain more points. Accumulative rating systems are

16 Stefani (2011) examines sports recognized by the IOC (106), by SportAccord (+26), as well as other listed in Wikipedia (+27). Mind sports are also included. Chess and bridge are recognized by the IOC, additionally draughts (checkers) and go are recognized by SportAccord and the International Mind Sports Association (IMSA), and a fifth game – xiangqi (sometimes called Chinese chess) – is a part of the SportAccord World Mind Games.

preferred when it is desirable to attract more participants in tournaments – the non-decreasing accumulation of points encourages competitors to enter as many events as possible. Usually a devaluation of the points won is implemented in these systems. This means that after a certain period of time the points won in past competitions will have less weight in the competitor's rating – competition inactivity will have a negative effect on the competitor's rating. The time window for evaluating the competitor's performance is mostly 1 year, but in some sports can reach up to 8 years. The devaluation is linear – for example, by 25% every year in a 4-year time window.

The adjustive rating systems are primarily used in object sports, where the competition consists of head-to-head matches, which allows adjusting the ratings considering the opponent's strength. These rating systems usually offer the best prediction of match outcomes because of their inherent predictor-corrector properties.

5. The Problem of the Olympic Medals Ranking

Prestige gain rankings are related to the Olympic medals rankings. The Olympic medals won in different disciplines become a unifying criterion, making an interdisciplinary comparison possible. It can be argued that the medals won as a whole are not really about which country is the “best” but rather show which country has gained most prestige from the Olympic games (the medals are trophies of prestige). The way to rank the countries according to the medals won has caused many hot discussions. The International Olympic Committee (IOC) does not consider its sorting of nations to be an official ranking system¹⁷.

However, the used lexicographic ranking system (also known as “gold first”)¹⁸ is considered by the general public to create a ranking. The drawback of such a ranking method is immediately revealed by the simple question: “What is better – 1 gold medal or 1000 silver?” Another alternative which widely circulates is the sum ranking system (i.e. total number of medals). The common sense tells that a system treating all medals equal is nonsense. Who would prefer 11 bronze medals to 10 gold?!

Another approach is to rank the countries on an equal basis using some demographic data such as population size (Churilov & Flitman, 2006) or to what extent the countries come up

17 "I believe each country will highlight what suits it best. One country will say, 'Gold medals'. The other country will say, 'The total tally counts'. We take no position on that." – IOC President Jacques Rogge.

18 The countries are sorted by the number of the gold medals won. If this number is equal, then the sorting continues by the number of silver, and then by the number of bronze medals.

to the expectations for success based on gross domestic product (Lins et al., 2003). This may seem reasonable because the population (more people, more to choose from), as well as financial resources (more money, better conditions) play a role in determining sporting success. However such systems don't have much chances to be widely accepted, because announcing a country as the greatest Olympic performer just because it is small or poor doesn't make much sense.

It seems that a weighted point system is the way to go. There have been different suggestions¹⁹. For example, a simple Fibonacci point system (3:2:1), where the gold medal is worth a silver + bronze medal. Similar to it is the 1908 London point system (5:3:1), which is with evenly increased value of the “better” medals. Winning gold in an Olympic discipline means to be *the* winner, being on the top with no one who is better. This fact puts more weight on being first. So the difference between gold and silver should be larger than between silver and bronze. The New York Times weighted point system (4:2:1), Luchies Olympic Formula point system (5:3:2), and the Topend Sports point system (6:2:1) take this consideration into account. We can also consider systems like (6:3:2) or (5:2:1) which seem fair. However the weights in all these systems are arbitrarily chosen, given by “intuition”. Sitarz (2012) uses a method based on the weighted mean value to get the mathematically sound weights (11:5:2). He also suggests a second method which uses volume-based sensitivity analysis. This method determines the rankings in a more complicated way without using weights for the medals (which is difficult to calculate). Sitarz (2013) comes up with the idea to use the incenter of a convex cone to obtain another set of weights for the medals – (6.3, 2.4, 1.0).

Soares de Mello et al. (2008) use a novel approach pointing out that in some disciplines there are more possibilities of winning a medal because of the more events. They also take into account the “impact” of each sport measured by the number of participating countries. Their method assigns different weights for the medals in the different sports.

All the point systems described so far are static, i.e. static weights are assigned to the medals won. Let's look from another perspective. If a country has no gold medals, it may prefer winning a gold medal to winning two silver and one bronze medals. But if the country already has 10 gold medals, then it may prefer winning the two silver and one bronze medals, because it will get three more medals instead of one. When there is

19 For more information see: www.topendsports.com/events/summer/medal-tally/rankings.htm (accessed on 25-07-2013)

enough quality, than the emphasis is on the quantity, and vice versa. These thoughts show that the preferences for winning a certain medal are dynamic and may change during the Olympic games according to the results.

6. The “TUGab Index” Ranking

Todorov & Belev (2010) have developed a system for measuring prestige gained by students of the Technical University of Gabrovo in competitions. The system is used to create the TUGab Index ranking. It includes all national and international scientific competitions since September 2004 in which students of the university have taken part. TUGab Index aims to preserve the achievements of the students and their contribution to the prestige of the Technical University of Gabrovo. Another goal of the ranking is to have a positive impact on the motivation for meaningful extracurricular activities and encourage the students to participate in competitions. The TUGab Index rankings are published on the main page of the university's website²⁰.

The prestige gain ranking system (PGRS) developed by Todorov & Belev (2010) is a hyperbolic accumulative system that puts a lot of weight on big achievements, but at the same time rewards every single participation in a competition. The students who are very successful (even only once) cannot be overtaken by other students who just participate multiple times. On the other hand, those students who don't have any competition success will still receive points with every further participation. In this way their persistence will be rewarded.

The main factor in PGRS determining the competition's prestige is the number of participants, on the premise that the more contestants, the greatest the victory can be. Bonuses are also awarded if a trophy (a medal, a cup, etc.) is won or the participant is a part of a team. The university students are ranked by their *Success Rating*, which is calculated from the students' final positions in the competition standings.

PGRS suits perfectly its purpose – to generate the TUGab Index rankings. But for a general use it has some weaknesses. However, in terms of creating a universal interdisciplinary ranking system the PGR system is the most appropriate one among all rating methods and systems which have been mentioned earlier in this chapter. This is why it was chosen as a basis in the further development of the new prestige gain ranking system called **UnIdRaS**.

20 www.tugab.bg

III. Concept of the **UnIdRaS** Ranking System

Within this master thesis the Universal Interdisciplinary Ranking System – **UnIdRaS** (pronounced [u'nidras]; alternative spelling “Unidras”) was developed. The main purpose of the ranking system is to evaluate and measure prestige gained by participants in competitions.

1. Properties of **UnIdRaS**

The ranking system has the challenging task to be universal and interdisciplinary, and to encourage the competitors to participate in competitions as much as possible.

1.1 Universality and Interdisciplinarity

The ranking system has to be applicable to all types of competition formats in order to be classified as universal. Example for such formats are knock-out (tennis), multistage (football), round-robin (volleyball), Swiss system (chess), etc. The interdisciplinarity requires the ranking system to support all competition fields – for example, all kinds of sports. How can this be achieved? How can we compare chess to swimming?²¹

To achieve the two properties, universality and interdisciplinarity, a common criterion for comparison in all competition needs to be found. What is the difference between competition and non-competition fields? In competitions we always get winners and losers, participants who perform better and other who perform worse. This is the main point used in the **UnIdRaS** ranking system. The final standings of the participants in competitions offer a common ground for interdisciplinary comparisons, regardless of the competition format.

1.2 Accumulative Type

One of the aims of the **UnIdRaS** ranking system is to stimulate further participation in competitions. This is why an accumulative type of ranking system is chosen (in preference to a subjective and an adjustive one), where it is not possible for the participants to lose points. In an adjustive systems the player's rating goes up and down, which poses a

21 The sports science team at ESPN has determined who the world's greatest athlete is, using their own methodology. More about it: www.topendsports.com/world/lists/fittest-athlete/athletes-espn.htm (accessed on 30-07-2013).

danger that the player takes no part in competitions in order to keep his/her high rating. This is also related to performance and mastery avoidance goals as motivation factors (Van Yperen, 2006). **UnIdRaS** is designed to relate to mastery approach goals, to be a motivator for the competitors to achieve, to get better, to do better.

2. **UnIdRaS** Prestige Rating

The designed ranking system **UnIdRaS** is very complex, taking into account various factors like competition field recognition, event categories, competition quality, competition diversity and many others. Generally the ranking system is of a hyperbolic type on the basis of the number of participants. The ranking system puts a lot of weight on good performances but at the same time rewards every participation in a competition. In this way players who have good performances cannot be overtaken by players with just a lot of participation, and persistent players will still get points every time they take part in a competition.

In elite competitions the number of participants doesn't play an important role. The competitors have already proven their mastery and the participation itself is prestigious. In case of an elite tournament the **UnIdRaS** system switches into close to linear mode, which is more suitable when dealing with the top players in the world.

The rating developed to rank the competitors in **UnIdRaS** is called **UnIdRaS** Prestige Rating (UPR) and is calculated by

$$UPR = \sum_{i=1}^n (TPG_i \cdot T_i), \quad (1)$$

where:

UPR – **UnIdRaS** Prestige Rating,

n – number of competitions in which the player has taken part,

TPG - Total Prestige Gain,

T - time devaluation.

The prestige gained from every competition is calculated according to

$$TPG = DR \cdot ER \cdot SC, \quad (2)$$

where:

TPG - Total Prestige Gain,

DR - Discipline Recognition,

ER - Event Rank,

SC – Success in Competition.

In the following sections the parameters for calculation of *UPR* are explained in details and default values are proposed. However, the users of the **UnIdRaS** software are able to change them and use the ranking system according to their own needs.

3. Discipline Recognition

The competitive disciplines are not identical. Of course, determining which discipline is “better” is very subjective. For example, football fans will appreciate achievements in football more than those in chess, and vice versa. But the common sense tells us that success in tennis will undoubtedly be higher appreciated than success in competitive eating²². The Discipline Recognition (*DR*) parameter aims to assign some scientifically grounded weight to distinguish between the quality of the disciplines.

One way to do this is to evaluate how hard it is to achieve success in a given field. Mitchell & Stewart (2007) build a competitive index for international sport. However, this method is not everywhere applicable because of lacking data. Another way to look at the problem is the field's popularity. Let's take sports as an example. But how do we define the most popular sport? The sport with the most fans²³ or the sport most widely played²⁴? How do we estimate the number of fans and the number of players? Also the results vary heavily from country to country. Therefore this method is unreliable.

The method chosen to determine *DR* is more robust, assigning weights to the different disciplines according to what extent the disciplines are recognized and organized in terms of official governing bodies. The weights are given in Table 4.

22 Competitive eating is a sport in which the participants have to eat large quantities of food in short time. The sport has an international federation - International Federation of Competitive Eating (www.ifoce.com). Organized professional eating contests offer sometimes \$10 000 in prize money.

23 www.mostpopularsports.net lists the Top 5 sports by estimated number of fans as follows: 1. Football (soccer), 2. Cricket, 3. Field Hockey, 4. Tennis, 5. Volleyball.

24 The IOC in its “Report on the 26 Core Sports for the Games of the XXXI Olympiad” gives the numbers of the member national federations of the corresponding international federations. Most widely played sports are Athletics (IAAF) and Basketball (FIBA) with 205 member national federations each, Volleyball (FIVB) – 204, Tennis (ITF) – 202, Aquatics (FINA) – 201. We see that cricket and field hockey are in the Top 5 by number of fans but they have about half the number of national federations compared to most widely played sports. This means that they are very popular in highly populated countries, but not played as much worldwide.

<i>Sport</i>	<i>Discipline Recognition</i>
Recognized by the International Olympic Committee	x 1.0
Recognized by SportAccord	x 0.9
Having an international federation	x 0.7
Having a national federation	x 0.4
Without any official governing body	x 0.1
<i>Science and other</i>	<i>Discipline Recognition</i>
Studied at school/university level ²⁵	x 1.0
Having traditional international competitions ²⁶	x 0.8
Having traditional national competitions	x 0.5
Newly emerged disciplines	x 0.2

Table 4: The Discipline Recognition parameter for different competition fields

Sports tend to be better organized regarding governing structures. This is the reason the other competition fields to have a higher *DR* compared to sports at the same level of organization. Sports have dedicated federations while the competitions in other fields are carried out by organizations with main activity different from managing the competition. This is why the requirement for sports is to have a federation at a certain level, and for other fields – to have a traditional competition at a certain level. “Traditional” is defined as having at least three past competitions.

It shouldn't be mistaken that the *DR* parameter is about the level of the competition (international, national, etc.); it is about the highest level at which competitions in a given discipline are organized, as an indicator for the quality of that discipline.

If the status of a discipline changes, the past events will not be recalculated, because the results and the prestige gains correspond to the situation at the time of the event.

4. Event Rank

It is unthinkable to treat a local championship in the same way as a world championship. Sports with accumulative ranking systems use different strategies to deal with the different rank of the competitions. For sports with a fixed number of known tournaments

²⁵ Such widely recognized disciplines are mathematics, informatics, physics, etc.

²⁶ An example for a competition in this category is FameLab (www.famelab.org) – a contest for science communication.

the players receive different points depending on the tournament²⁷. Other sports have a multiplier for the rank of the competition²⁸. Another but inferior strategy would be to include in the rankings only tournaments of the same rank.

To distinguish between the competitions' ranks a parameter called Event Rank (ER) is introduced in **UnIdRaS**. It is calculated according to

$$ER = BR \cdot DF \cdot RF, \quad (3)$$

where:

ER – Event Rank,

BR – Base Rank,

DF – Diversity Factor,

RF – Restrictions Factor.

4.1 Base Rank

All competitions are divided into 7 categories and to each category a parameter called Base Rank (*BR*) is assigned. *BR* determines the main weight of the competitions in a given category. Generally every category can be seen as a composition of multiple instances of a lower category (not necessarily the very next one). A higher category event should²⁹ have at least two representatives of a lower category, referred to as subunits. For example, an international competition should have at least two participating countries; a regional event should have at least two sports clubs from different cities (but as subunits are considered the clubs, because bigger cities may have many clubs). In this line of thoughts the *BR* of every category is the doubled lower category weight. All weights are given in Table 5.

- The lowest category are internal events. They are intended for a limited group of people, within an organization or on a certain occasion. For example, tournaments organized for the members of a sports club.

27 For example in tennis, the winners of Grand Slams get 2000 points for the rankings and winners of ATP World Tour Masters 1000 get 1000 points.

28 Some examples. In basketball the event weight ranges from 0.1 for an Oceania Championship to 5.0 for the World Cup and the Olympic games. In football the “importance of match” parameter is 1 for a friendly match and 4 for the World Cup final competition. In sailing the grade multiplier has a minimum value of 1.0 for regional and exhibition events and a maximum of 3.5 for the world championship.

29 It may be not so if the competition has an official status of a competition of a certain rank.

<i>Rank of Event</i>	<i>Type of Event</i>	<i>Base Rank</i>
Category A	World championships, Olympic games	x 64
Category B	Intercontinental	x 32
Category C	International	x 16
Category D	National	x 8
Category E	Regional	x 4
Category F	Local	x 2
Category G	Internal	x 1

Table 5: Event classification and the Base Rank multiplier

- Local events are competitions with participants from a limited (small) area. Such events can be, for example, city championships. Exceptions are the city championships of the capitals of the countries which should be considered as regional events because of their importance.
- Regional events are competitions between cities or clubs in a given region. Such an event is, for example, the university volleyball championship of Saxony, Germany.
- National events are competitions open for everyone within a country. As subunits can be considered cities, sports clubs, universities, etc.
- International competitions are those in which representatives of more than one country within a continent take part.
- To be classified as an intercontinental competition it has to include participants from at least two continents³⁰. A problem is posed by transcontinental countries³¹ which have territories on two continents. The classification of the United Nations Statistics Division³² is used to resolve the problem. It states that the main continent of a country is in which the most of the population lives³³.
- The highest ranked championship, Category A, must have an official status of a world championship. The only exception are the Olympic games.

30 The 7 continents are: Europe, Asia, Africa, North America, South America, Australia, Antarctica. Although there are no countries in Antarctica, it is not theoretically excluded that scientists from the bases there take part in competitions.

31 As transcontinental countries are considered: Azerbaijan, Egypt, Georgia, Kazakhstan, Russia, Turkey.

32 unstats.un.org/unsd/cr/ctryreg/default.asp?Lg=1 (accessed on 29-07-2013).

33 The two most controversial countries are Russia and Turkey. According to the definition of the United Nations Statistics Division, Russia belongs to Europe and Turkey to Asia.

If an event has an official status³⁴ of a competition of a certain level, the officially announced category of that event is the exact category in which the event is registered in the rankings. For example, if in a national competition a team from another country takes part, the competition remains a national event and the external participant is counted as an internal one. Another example – an European championship includes transcontinental countries, which according to the definition of the United Nations Statistics Division have Asia as a primary continent. This European championship cannot be regarded as an intercontinental. On the other hand, we may have the opposite case. For example, a competition has an official status of an international event but only national participants take part. In such a case the event still remains international.

4.2 Diversity Factor

Competitions of the same rank may not be identical. A win in an international tournament with 30 participating countries will definitely bring more prestige than a win in a similar tournament but with only two participating countries. To implement this, a parameter called Diversity Factor (DF) is introduced, which is a bonus multiplier from which competitions with a greater number of participating subunits benefit. For internal events DF always equals to 1, because no subunits can be defined for the lowest category³⁵.

It is reasonable that the minimum number of subunits in a competition of a given category should be 2. So if there are only two subunits in a competition, DF has to be equal to 1. Also the product $BR.DF$ should never reach the BR of the next higher event category. Therefore DF should be less than 2 for any number of subunits (U). These two conditions that need to be satisfied are mathematically expressed as

$$\left| \begin{array}{l} DF(2) = 1 \\ \lim_{U \rightarrow \infty} DF(U) = 2 \end{array} \right. , \quad (4)$$

34 Assigned by the governing body of that discipline or by an official organization, or widely accepted as having such status.

35 It can be argued that a world championship is a world championship and the number of nations is not an indicator for the quality of this highest level of competition – the best players in the world can be from the same country/continent (i.e. there should not be a Diversity Factor for world championships). This is true, but let's imagine a final for a world championship where the two players come from the same country, and another one with the two players being from different countries. In the second case the response in the society of the winning country will be higher because of the people's inherent tendency of national identification. In the first case the event will be seen more or less as a national competition.

where:

DF – Diversity Factor,

U – number of subunits.

There is a significant difference in the perception of the scale of a competition if, for example, 3 subunits take part in it instead of 4, compared to 103 instead of 104. DF takes this into account. It increases faster when there are relatively few subunits, and slower when the number of subunits is relatively high. Functions (5) were considered as potentially suitable for calculating DF .

$$\begin{aligned}
 (a) \quad & 2 - \frac{1}{\log_2 x} & (b) \quad & 2 - \frac{1}{\log_3(1+x)} & (c) \quad & 2 - \frac{1}{\log_4(2+x)} \\
 (d) \quad & 2 - \frac{2}{x} & (e) \quad & 2 - \sqrt{\frac{2}{x}} & (f) \quad & 2 - \sqrt[3]{\frac{2}{x}}
 \end{aligned}
 \tag{5}$$

These functions are plotted on Figure 1.

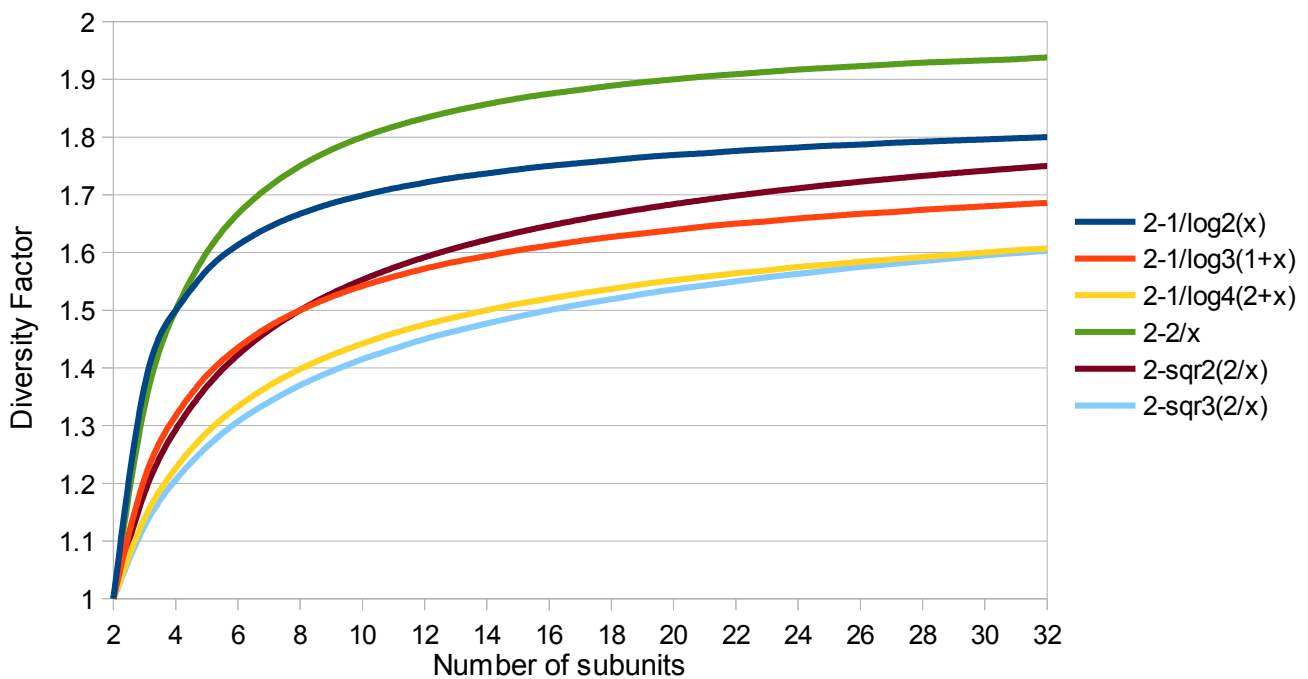


Figure 1: Comparison between functions for the calculation of the Diversity Factor

Functions (a) and (d) increase too fast in the beginning, and (c) and (f) – too slow. Functions (b) and (e) both reach 1.5 at 8 subunits. The essential difference between the latter two is at larger number of subunits, where (b) reaches 1.75 at 80 subunits, and (e) at 32. Function (e), $2 - \sqrt{2/x}$, was preferred as it comes closer to the upper value at a more reasonable number of subunits.

Another thing to consider is that competitions of the same category, with an equal number of participating subunits, can still quite differ – an international competition with 30 participants, only 1 coming from a second country, is not the same as a competition where the participants from the second country consist 50% of the whole. To deal with this matter a parameter called Homogeneity (H) is introduced. H sets a threshold to distinguish between “true” and “pseudo” events in a given category (e.g. a truly-international and a pseudo-international tournaments). H is calculated as a ratio between the number of participants from the largest subunit to the number of all participants according to

$$H = \frac{M}{N}, \quad (6)$$

where:

H – Homogeneity,

M – number of participants from the largest subunit,

N – number of all participants.

The threshold is set to $H = 0.75$. This means that the participants from a single subunit should not exceed 75%, otherwise the event is considered as a “pseudo” one and gets less DF than a “true” competition (of the same category) with two subunits. For example, in an international competition with 100 participants no single country should have more than 75. DF is calculated by

$$DF = \begin{cases} 2 - \sqrt{\frac{2}{U}}, & H \in (0, 0.75] \\ \frac{2.75 - H}{2}, & H \in (0.75, 1] \end{cases}, \quad (7)$$

where:

DF – Diversity Factor,

U – number of subunits,

H – Homogeneity.

From (7) we can see that if H is from 0.0 to 0.75 ($H = 0$ is impossible), DF ranges from 1.0 toward 2.0 (if $U = 1$, then $H = 1$). And from 0.875 toward 1.0³⁶, if H is between 1.0 and 0.75.

36 “Pseudo” events may bring less prestige than “real” events of a lower rank. The boundary case is a competition with only one subunit ($U = 1$, $H = 1$, $DF = 0.875$). Taking into account the BR difference of the categories, we get $DF' = 1.75$. After some calculations we can see that if participants from more than 32 subunits take part in an equivalent lower ranked competition, they would receive more prestige points than those in the higher ranked “pseudo” event.

4.3 Restrictions Factor

Beside the open competitions, where everyone is allowed to take part, and the elite tournaments, where only personally invited players may participate, there is a third kind of competitions – the restricted ones. In them everyone who matches certain conditions is allowed to participate. Such competitions are all “under age” contests, where the age of the participants is limited; or competitions only for women/veterans/students; or amateur events, where only players with rating below a certain level may take part. Also competitions for disabled people are restricted events. As restricted events count only those with an upper bound restriction, i.e. the proficiency level of the entrants is artificially limited. Professional events with a lower bound restriction (where no amateurs are allowed) are not considered as restricted.

Winning an open world championship brings definitely more prestige than winning the same world championship in the “Under 10”³⁷ age group. To deal with this matter the Restrictions Factor (RF) is introduced³⁸. While the situation with the age groups is clear, other restriction kinds are controversial.

Such controversial group are women events. In physical sports women and men compete in separate categories and being successful as a man or a woman is arguably equally prestigious. In mind sports like chess women have separate events but also compete in open events along with men (but may receive extra prizes; such prizes may be received by age and rating groups too).

Competitions for students and university students are usually doesn't exist for other groups, i.e. one can participate in such competitions only while being a student / university student. This is why $RF = 1$ is proposed for these competitions.

Competitions for amateurs may vary depending on the restrictions' type. **UnIdRaS** software allows creation of new types of restrictions and editing the predefined ones. Table 6 contains the proposed RF values for different target groups.

37 “Under age” groups are referred to as U20, U18, etc. Some sports, like volleyball, have separate rankings for the “under age” groups. Other sports, like chess, have also separate rankings for “under age” groups, but these “under age” competitors are included in the main ranking too.

38 Another strategy, which is applied by the International Table Tennis Federation (ITTF), is to classify the “under age” competitions as lower ranked events.

<i>Group</i>	<i>RF</i>	<i>Group</i>	<i>RF</i>
Unrestricted	1.00	U19	0.63
Women	1.00	U18	0.58
University A	0.97	U17	0.54
University B	0.95	U16	0.50
University C	0.93	U15	0.45
School	0.90	U14	0.40
Seniors/Veterans	0.85	U13	0.35
Amateurs	0.80	U12	0.30
Disabled people	0.75	U11	0.25
U23	0.75	U10	0.20
U22	0.73	U9	0.15
U21	0.71	U8	0.10
U20	0.66	U7	0.05

Table 6: Restrictions Factor proposed for different target groups

5. Success in Competition

The greatness of a win generally depends on the number of opponents defeated. The more opponents, the greater the competition, the greater the prestige gain potential. This is why the number of participants is the main measure in **UnIdRaS**. The exception are elite events, where the number of participants doesn't govern the prestige perception of a tournament anymore. Such cases are also covered by **UnIdRaS**.

Success in Competition (SC) measures how good participants perform in competitions:

$$SC = MP + EB, \quad (8)$$

where:

SC – Success in Competition,

MP – Main Prestige,

EB – Elite Bonus.

The formula has two parts – the first one refers to competitions in general and the main prestige gained, and the second one deals with elite competitions, where the world's best players participate.

5.1 Main Prestige

What is the perception about the prestige that should be assigned to every position in the competition standings? The most attention goes to the winners, and rapidly decreases with every further ranking position. This common and natural observation is the reason a hyperbolic ranking system type to be chosen. The Main Prestige³⁹ (MP) is calculated by

$$MP = N.P^{-QP}, \quad (9)$$

where:

MP – Main Prestige,

N – number of participants,

P – position of the participant in the final standings of the competition ($1 \leq P \leq N$),

QP – Quality Premium.

The distribution of the rating points for a competition with 50 participants can be seen on Figure 2. It corresponds to the natural perception of the prestige related to the positions in the competition standings.

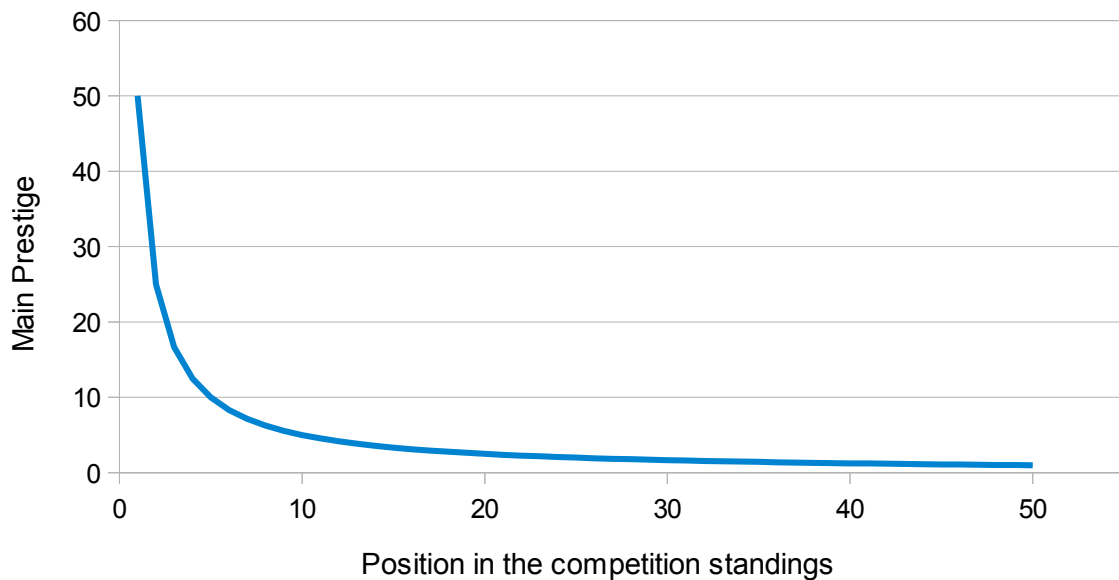


Figure 2: Success in Competition (50 participants, no Quality Premium)

In hyperbolic ranking system types the emphasis is on big achievements. This means that who has a big success, being on one of the first places, can hardly be overtaken by others

39 The formula was originally used by Todorov & Belev (2010) to calculate the TUGab Index ratings.

who just participate multiple times without performing considerably well. At the same time the persistence of the latter is rewarded, as they always get points with every participation.

How is it in other disciplines? The points distribution heavily varies but follows a similar pattern in most cases: in Formula 1 only the first 10 positions get points; in Badminton up to 1024 participants are rewarded; in darts the number of competitors receiving points depends on the number of entrants in the competition; in TUGab Index (where the same hyperbolic system as in **UnIdRaS** is used) every participant gets points in a hyperbolic manner; in sailing also all participants get points but in a linear way⁴⁰.

On Figure 3 the normalized distribution of ranking points depending on the final position for various sports is given⁴¹. The hyperbolic pattern can clearly be seen. The ranking points distributions in tennis and golf are very similar to the one in TUGab Index.

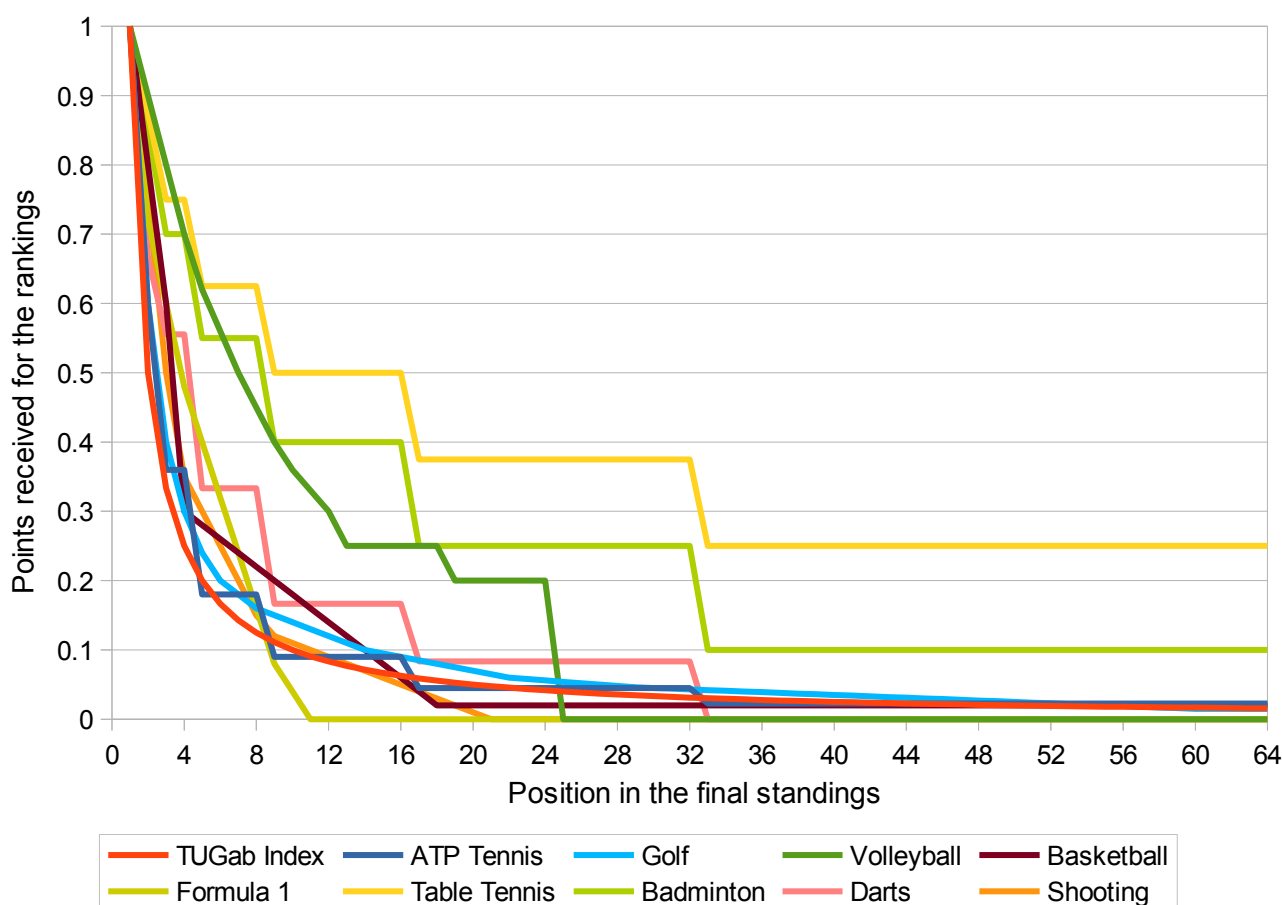


Figure 3: Comparison between ranking points distributions in various sports

⁴⁰ Linear distribution of points is suitable for elite events.

⁴¹ The data is collected from the official websites of the sports federations. The points distribution from the highest ranked competition in the given sport is used.

5.1.1 Quality Premium

Two competitions with exactly the same rank and number of participants can still be different in terms of the prestige they bring. They can provide some conditions to increase their reputation.

One way to make a competition more prestigious is by offering trophies as prizes. One who wins a trophy is undoubtedly seen as more prestigious than someone who achieves the same position but without a trophy. As trophies are regarded medals, cups, bows, statuettes and other “objects of fame” that have no other purpose than serving as competition trophies. Non-trophies are diplomas, certificates, money prizes⁴², non-competition objects, vouchers for trips and services, subscriptions, etc.

Another way to increase the prestige of a competition is to offer a team ranking in addition to the individual one. In general team sports get more attention from the public than the individual ones⁴³ and so the team events.

The Quality Premium (QP) increases the points from a competition if one or two of the above mentioned options are available. QP is calculated according to

$$QP = 1 - \frac{\sqrt{v} + \sqrt{w}}{2}, \quad (10)$$

where:

QP – Quality Premium,

v – trophy bonus,

w – team bonus.

5.1.2 Trophy Bonus

The trophy bonus is calculated according to

$$v = \begin{cases} \frac{1}{V}, & \text{a trophy has been won} \\ 0, & \text{none won or no trophies} \end{cases}, \quad (11)$$

42 Money prizes will eventually attract more participants and will make indirectly the tournament more prestigious.

43 According to www.mostpopularsports.net 4 of the top 5 sports are team sports, and the fifth has also a team mode.

where:

v – trophy bonus,

V – position for which the trophy is awarded.

It shows whether a trophy has been won, if trophies are provided. If more than one trophy is won (e.g. an individual and a team trophy), then the better one is taken into account, therefore V can be the individual or the team place for which the trophy is officially awarded. It should be noted that this position may differ from the place taken (P) because of the standings' normalization.

5.1.3 Team Bonus

The team bonus is calculated by

$$w = \begin{cases} \frac{1}{W}, & \text{the player is a part of a team} \\ 0, & \text{an individual player or no team ranking} \end{cases}, \quad (12)$$

where:

w – team bonus,

W – normalized position of the team in the team standings.

It is awarded if the competitor is a part of a team (in case of team rankings). In team-only competitions the team bonus is always awarded.

In Figure 4 is shown how the ranking points from a competition increase if there is a Quality Premium. The only exception is the winner who serves as a reference point and is not affected by QP .

Winning a trophy when even not being at a head position⁴⁴ gives a boost to the prestige gain. Also being a part of a top team increases the gained prestige dramatically. One can also notice that there is quite a difference between being a part of a team on the 2nd or 3rd place (or worse) and being a part of the winning team. Being on the very top is always plentiful rewarded. It can also be noticed that winning a trophy and being a part of a team simultaneously brings more points than the points from the two counted together. This is a kind of bonus for those who achieve both things at the same time.

⁴⁴ For example, in the international Olympiads in Mathematics and Informatics half of the participants receive medals.

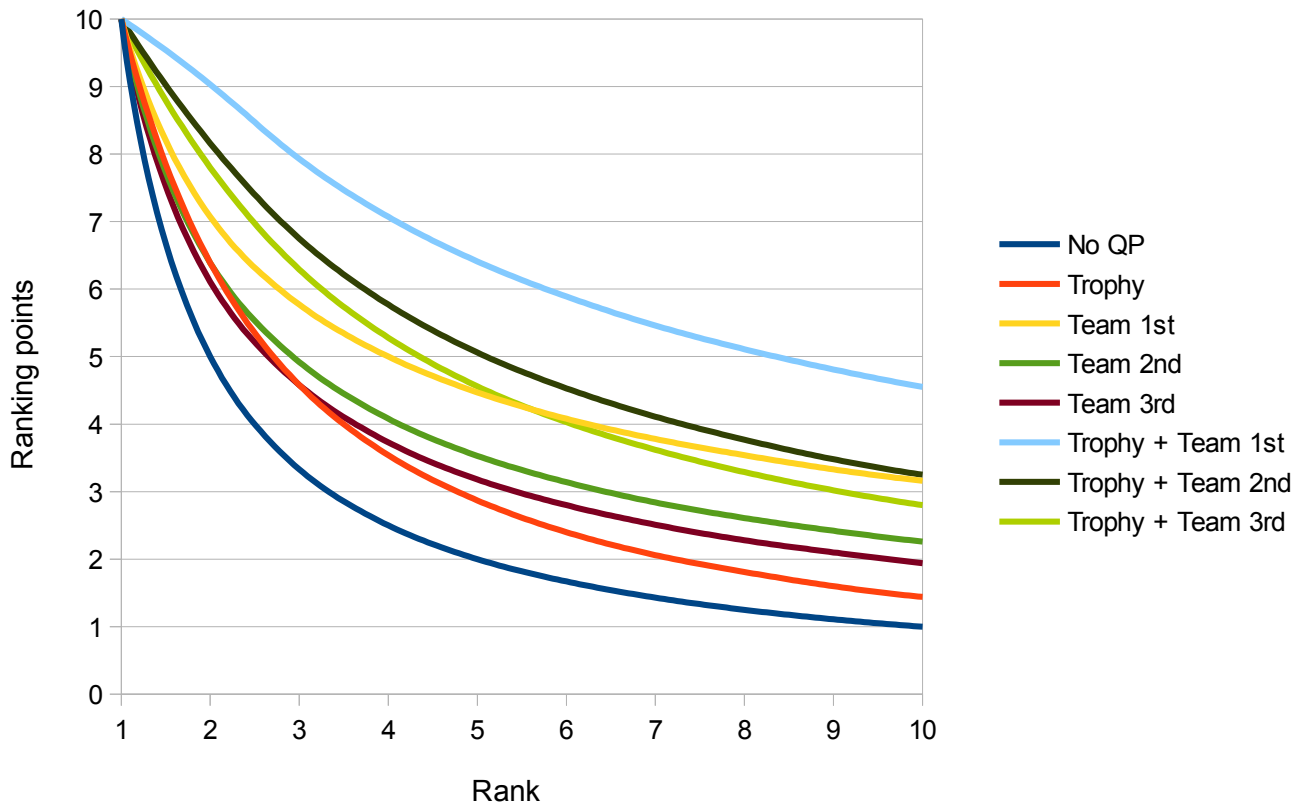


Figure 4: Increase of the ranking points related to the Quality Premium

5.2 Elite Bonus

The Elite Bonus (EB) has the purpose to reward events in which world's top players take part. If a discipline does not provide a world ranking list of a kind TOP Z^{45} , then no *EB* is rewarded ($EB = 0$). The reason is that without a ranking list the people don't know who the best players are, therefore it makes no difference (in a prestige gain point of view) if they take part.

EB is calculated according to

$$EB = CP \cdot EL \cdot MB, \quad (13)$$

where:

EB – Elite Bonus,

CP – Competition Performance,

EL – Elite Level,

MB – Maximal Bonus.

⁴⁵ It can be, for example, TOP 10, TOP 50, TOP 100, etc.

5.2.1 Competition Performance

Competition Performance (CP) is defined as the position reached in the final ranking in a competition compared to the first place. CP is calculated by

$$CP = \frac{N+1-P}{N}, \quad (14)$$

where:

CP – Competition Performance,

P – position in the final standings,

N – number of participants.

CP distributes linearly part of the maximal number of bonus points among the elite competitors. At the highest level of competition the number of players taking part doesn't play a major role for the quality of the tournament. Often these tournaments are closed events and only invited players are allowed to take part, therefore the participation itself is prestigious. That's why a linear system for distributing the bonus points is chosen rather than the hyperbolic one used in the general case.

5.2.2 Elite Level

The Elite Level (EL) depends on how many of the elite players in the world participate in a given competition, compared to the maximum possible⁴⁶. The elite players are defined as those included in the TOP Z ranking of the discipline in question. Not all elite players are equal. It brings more prestige if player Number 1 takes part in the competition than Number 2; Number 2 than Number 3 and so on. Because of that every elite player gets a score according to his/her rank⁴⁷, and non-elite players (not in the TOP Z ranking) get a zero score. The sum of the scores of the participating elite players are divided by the points if all participating players were the top elite ones.

46 A ranking system that takes into account the quality of the participants is used by FAI for all hanggliding and paragliding disciplines.

47 Another alternative would be instead of ranks to use the ratings in a given discipline. However this method has the following drawbacks: 1) there might be no utilizable ratings; 2) the ratings might need a transformation – some of them might be of type “more is better” and other – “less is better” (e.g. when it is about time); 3) the ratings would need additional scaling to fit a proper range. One more reason: imagine the following news cut: “Incredible! Dimitrov defeated Djokovic, the Number 1 in tennis!”, compared to: “Incredible! Dimitrov defeated Djokovic, rated 12310 in tennis!” The first statement says much more to the average person, who is not necessarily a tennis fan. And **UnIdRaS** is about gaining prestige in general; that is why the rankings, and not the ratings in the disciplines will be used for calculating the Elite Bonus.

The formula for the calculation of the Elite Level is

$$EL = \frac{1}{S} \sum_{i=1}^E (Z+1 - R_i), \quad (15)$$

where:

EL – Elite Level,

S – maximum elite score,

E – number of participating elite players,

Z – number of elite players in the world (in this discipline),

R – world rank of a participating elite player, $R \in [1, Z]$.

The maximum elite score is calculated by

$$S = \begin{cases} \frac{N(2Z - N + 1)}{2}, & N < Z \\ \frac{Z(Z+1)}{2}, & N \geq Z \end{cases}, \quad (16)$$

where:

S – maximum elite score,

N – number of participants,

Z – number of elite players in the world (in this discipline).

Example

The World Chess Federation publishes a ranking of the top 100 chess players ($Z=100$). If we have a tournament with 8 players, who are, let's say, #1, #3, #4, #5, #7, #10, #11 and #24 in the world, we calculate the following Elite Level

$$EL = \frac{100+98+97+96+94+91+90+77}{(200-8+1)8/2} \approx 0.96.$$

This means that the quality of such tournament is 96% of the strongest possible tournament in the world (in which players ranked #1 through #8 would take part).

5.2.3 Maximal Bonus

The Maximal Bonus (MB) determines the points for a perfect elite competition. An elite competition is a competition in which at least one elite player takes part. A perfect elite competition with N participants is a competition in which the top N elite players take part.

MB should change with the number of participants, because the more participants, the better the competition.

A Bonus Base (B) is defined to determine the bonus points for a perfect 2-player elite tournament. The B is set to 100, which means that the bonus for winning a perfect 2-player elite tournament is equivalent to a 100-player non-elite tournament win (assumed all other parameter values are the same).

A set of functions applicable for calculating MB are listed in (17) and plotted on Figure 5. An appropriate function should be equal to B when $N=2$, increase fast in the beginning, and then slower. The perception of being an elite player decreases the lower ranked one is. The more elite players take part in a tournament, the lower the average elite level is. The chosen function should be in accordance with this observation.

$$\begin{aligned}
 (g) \quad & B \log_{1.75}(N-0.25) & (h) \quad & B \log_2 N & (i) \quad & B \log_3(N+1) \\
 (j) \quad & B^{1.75} \sqrt[1.75]{N-1} & (k) \quad & B \sqrt{N-1} & (l) \quad & B \sqrt[3]{N-1}
 \end{aligned} \tag{17}$$

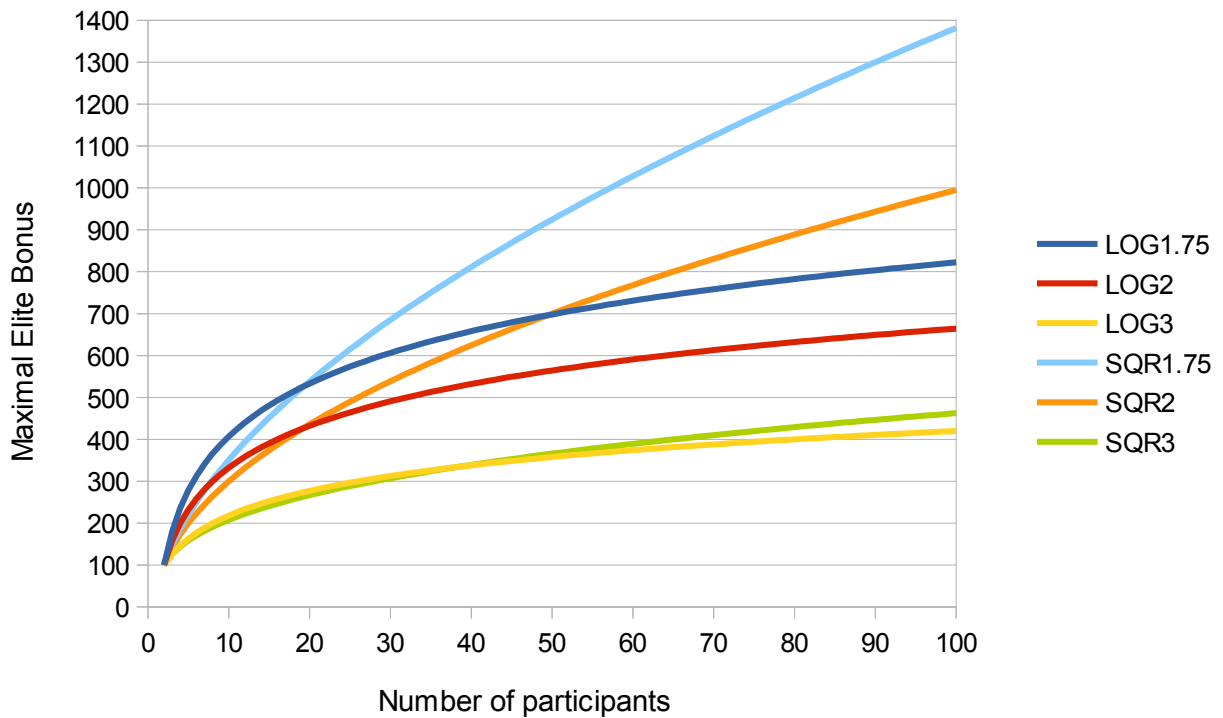


Figure 5: Candidate functions for calculating the Maximal Bonus

The square functions (j), (k) and (l) are not suitable, because they don't increase slower at greater values of N . From the logarithmic functions (g), (h), (i) as most appropriate was found to be

$$MB = B \log_2 N, \quad (18)$$

where:

MB – Maximal Bonus,

B – Bonus Base,

N – number of participants.

It determines the bonus for winning a perfect 8-player elite tournament as equivalent to a 300-player non-elite tournament win.

The ranking points that can be won from a 16-player competition are shown on Figure 6. They depend on the final position of the competitor and the elite level of the competition. When the competition is a non-elite ($EL = 0$) one, we have the standard hyperbolic function, heavily depending on the number of participants (QP is set to 1). This can be better seen on Figure 7, where the Bonus Base of the elite tournaments is set to 10 (instead of the standard 100) to reduce their influence.

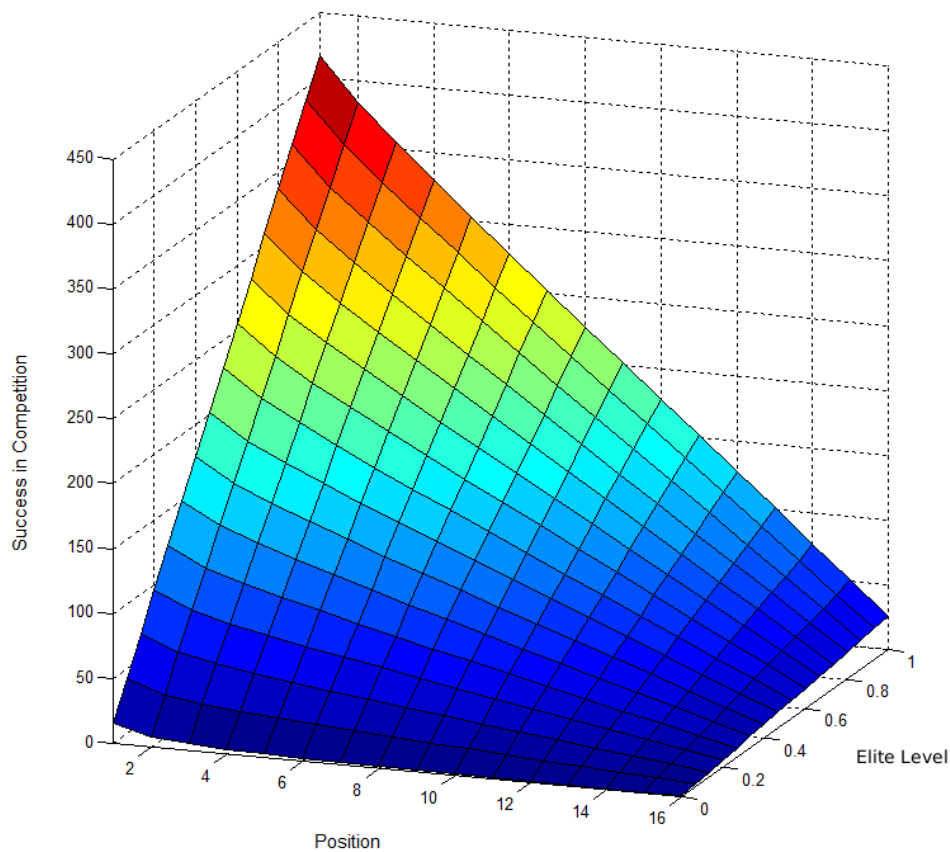


Figure 6: Ranking points that could be won from a 16-player competition

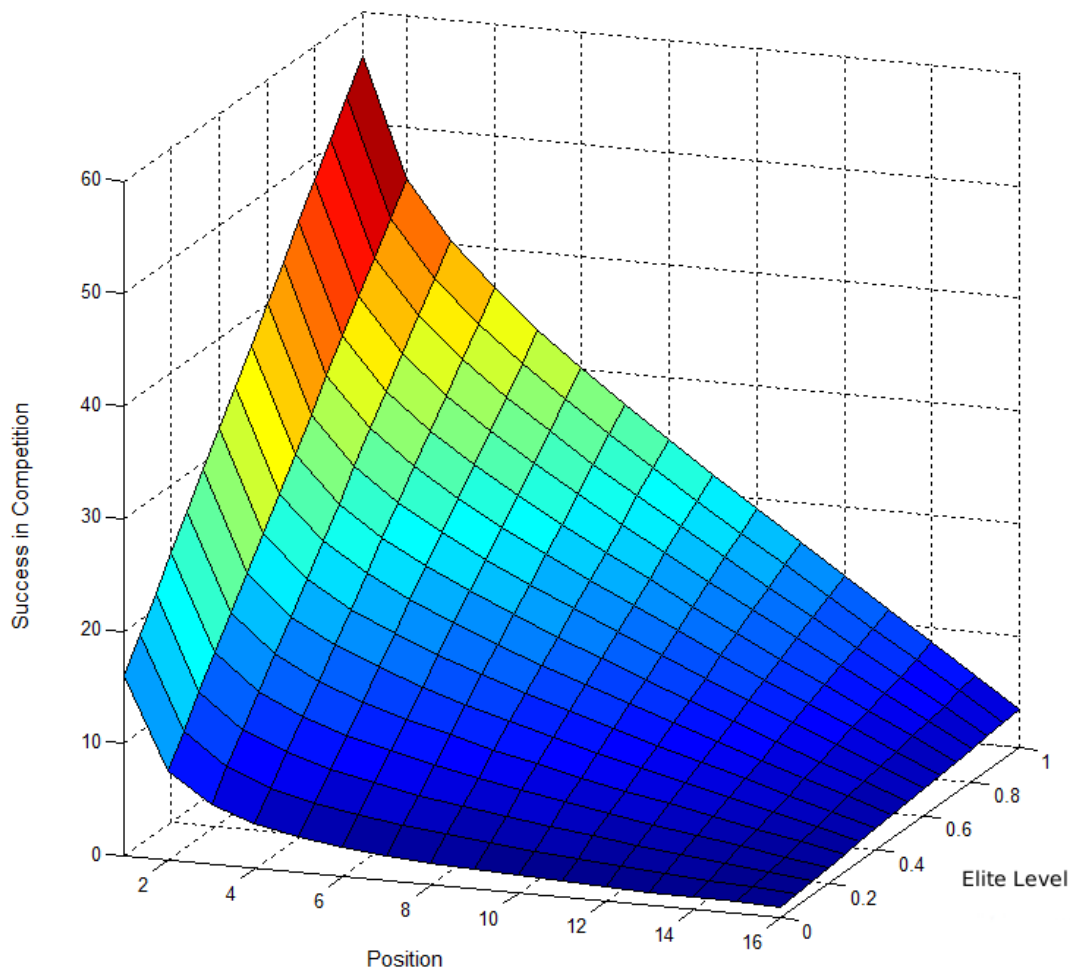


Figure 7: Ranking points for a 16-player competition with decreased Bonus Base

6. Time Devaluation

Whether a time devaluation (T) needs to be implemented or not depends on what kind of rankings we want to have. No time devaluation ($T = 1$), means that we generate “all times best” rankings. A remarkable example for such ranking is the one by the World Federation for Chess Composition (WFCC). The federation maintains a ranking of all chess composers who have created approved chess problems since 1914⁴⁸ with all deceased composers remaining in the rankings. Another “all time best” ranking is the TUGab Index of the Technical University of Gabrovo. It is a ranking of university students who have taken part in (approved) competitions since 2004. It is reasonable for this ranking to be an “all time best” one because one can participate in these competitions only while being a regular student at the university.

⁴⁸ The rankings are updated in three-year periods. There are 2037 chess composers and 21 467 chess compositions included in the full rankings that can be found in the Handbook of Chess Composition, 5th edition, downloadable at www.wfcc.ch. The latest rankings (as of 2009) on the website include only the Grandmasters in chess composition: www.wfcc.ch/fide-albums/points0406/ (accessed on 01-08-2013).

On the contrary, sports need dynamic rankings and because of that they implement time devaluation. Chartier et al. (2011) show how four basic weighting schemes (uniform, linear, logarithmic, step function) can be used in sports. Langville & Meyer (2012) mention also the exponential scheme. Stefani (2011) makes a summary what aging schemes are used in sports. Most of the sports (55) use a one-year data window, i.e. for ranking purposes they use only performances within the current season. The other 29 sports use a 2-, 3-, 4-, 7- or 8-year data window with an annual linear step devaluation of the results.

In **UnIdRaS** one can choose to have or not to have a time devaluation. In the first case a linear step function is available with adjustable time unit (years, months, weeks or days), step and data window. T is calculated according to

$$T = \begin{cases} 1 - \frac{\lfloor TG \cdot SD^{-1} \rfloor}{\lfloor DW \cdot SD^{-1} \rfloor}, & TG < DW \\ 0, & TG \geq DW \end{cases}, \quad (19)$$

where:

T – time devaluation,

TG – time gap between now and the end of the competition,

DW – data window, outside which the competition data is discarded,

SD – step of devaluation.

Example 1

A player has taken part in two tournaments – one in 2009 and one in 2011. The ranking system has a data window $DW = 4$ (tournaments outside the 4-year data window, starting from the current year, are discarded) and a step of devaluation $SD = 1$ (the competition data is devalued annually). As of 2013, we have for the tournament in 2009 $TG = 4$ (2013 – 2009), therefore the competition data is discarded. For the tournament in 2011 we have

$$T = 1 - \frac{\lfloor 2/1 \rfloor}{\lfloor 4/1 \rfloor} = 1 - \frac{2}{4} = 0.5,$$

which means that the tournament result enters the rankings with a 50% weight.

Example 2

Let's assume that we have a data window of 25 months ($DW = 25$), bi-monthly devaluation ($SD = 2$), and as of August 2013, a tournament result from November 2011 ($TG = 21$). We make the following calculation

$$T = 1 - \frac{\lfloor 21/2 \rfloor}{\lfloor 25/2 \rfloor} = 1 - \frac{10}{13} \approx 0.23.$$

The two examples are illustrated on Figure 8.

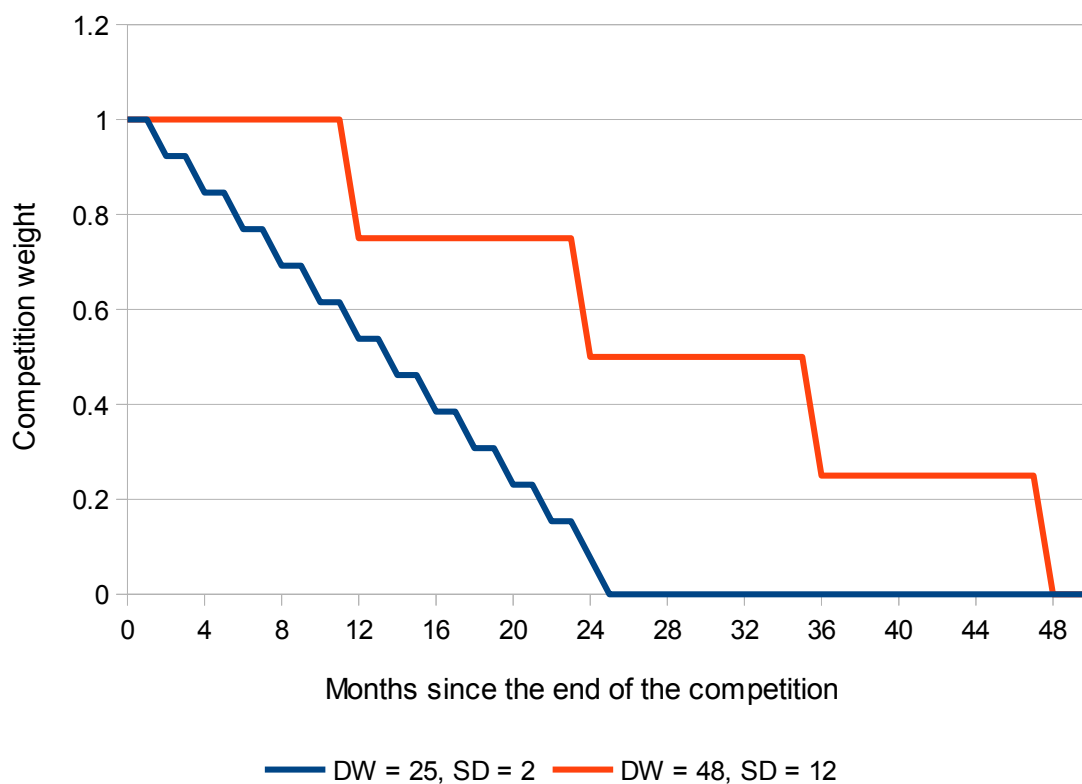


Figure 8: Competition weight in relation to the time devaluation

7. Normalization of Competition Standings

The competition standings may often differ in the system used for ranking the competitors. This may negatively influence the objectivity of the **UnIdRaS** rankings. This is why all ranking systems are converted to only one type before using the competition data. Four main ranking systems exist.

Standard competition ranking ("1 2 2 4") – players who achieve equal results receive the same ranking number. One says that they have, for example, a joint second place. After the joint position there is a gap to compensate the joint position, so that the number of participants remains equal to the number of positions in the standings. The drawback of this ranking system is that it treats the single and joint places the same. In reality to be first and to be joint first is not really the same. To win a competition alone brings more prestige than to share the win with some opponent(s).

Dense ranking ("1 2 2 3") – this ranking system is similar to the one above with the difference that there are no position gaps in the rankings. This brings a second drawback – the number of participants can be greater than the number of positions in the standings.

Ordinal ranking ("1 2 3 4") – in this system all players receive distinct ordinal numbers, including the players that compare equal. And exactly this is the drawback – some positions need to be decided arbitrary with methods that have nothing to do with the competition (for example tossing a coin).

Fractional ranking ("1 2.5 2.5 4") – players that compare equal receive the same ranking number, which is the mean of what they would have under ordinal rankings. One says that they, for example, share second-third place. This system has virtually no drawbacks and this is the reason to be used in **UnIdRaS**.

Competition standings made in conformity with the first three systems are always converted to the fractional ranking system before being used. Examples for conversions are given in Tables 7, 8 and 9.

Examples for conversion

<i>Old Position</i>	<i>Standard competition ranking</i>	<i>New Position</i>	<i>Fractional ranking</i>
1	Player A	1	Player A
2	Player B	2-3	Player B
2	Player C	2-3	Player C
4	Player D	4	Player D
5	Player E	5	Player E

Table 7: Conversion from standard competition ranking to fractional ranking

<i>Old Position</i>	<i>Dense ranking</i>	<i>New Position</i>	<i>Fractional ranking</i>
1	Player A	1	Player A
2	Player B	2-3	Player B
2	Player C	2-3	Player C
3	Player D	4	Player D
4	Player E	5	Player E

Table 8: Conversion from dense ranking to fractional ranking

<i>Old Position</i>	<i>Ordinal ranking</i>	<i>New Position</i>	<i>Fractional ranking</i>
1	Player A (points: 5, time: 23 min.)	1	Player A
2	Player B (points: 3, time: 12 min.)	2	Player B
3	Player C (points: 3, time: 17 min.)	3	Player C
4	Player D (points: 0, time: 0 min.)	4-5	Player D
5	Player E (points: 0, time: 0 min.)	4-5	Player E

Table 9: Conversion from ordinal ranking to fractional ranking

A fractional position is calculated as the mean of the shared places. For example, if 6 participants share places from 3 to 8, they all get the $(3 + 8)/2 = 5.5^{\text{th}}$ place.

There are contests where only the top few competitors are distinguished and all other get no distinct placing. In such a case all these participants can share the places behind the winners. For example, a contest with 50 participants, from which 10 are chosen as finalists, and then from these 10 the first three places are determined. In such a scenario we calculate the following positions:

$$P_1 = 1,$$

$$P_2 = 2,$$

$$P_3 = 3,$$

$$P_{4-10} = (4 + 10)/2 = 7,$$

$$P_{11-50} = (11 + 50)/2 = 30.5.$$

8. Special Cases

Some special cases with certain types of events might occur. A lot of them will be discussed here, but if an unregarded situation happens, it is up to the administrator of the rankings to decide how to proceed and resolve the ambiguous cases.

8.1 Team Competitions

In team competitions the team standings are converted into individual standings, where the players of one team share a sequence of places, depending on the position of their team in the team standings. For example, if there are 8 teams with 6 players each, we calculate for the players of the team that takes 5th place: $P_{[4 \times 6 + 1] - [5 \times 6]} = (25 + 30)/2 = 27.5$ place. Also the team bonus (12) always applies. This method of calculation was preferred to the alternative every player to receive the position of his/her team, because in team competitions less teams participate in comparison to the number of players in individual events. The alternative method of calculation would be a discrimination towards team events.

In team competitions with a secondary individual ranking, an individual trophy that may be won may play a role as a trophy bonus (11) if it is better than an eventual team trophy.

In individual competitions with a secondary team ranking (usually computed as a sum of the scores of a definite number of individual players) the players who are a part of a team receive the team bonus (12).

If the teams themselves are the important subjects, they can be entered as separate participants in the rankings and in this way to have rankings of teams.

8.2 One-in-Many Competitions

There are competition formats in which players take part in different (small) competitions throughout the year, and at the end all points they have won are counted together (or just the best result is taken). This result is used to create a final ranking for the overall event (which is usually of a higher rank). This overall ranking is treated as a separate competition in the **UnIdRaS** rankings.

8.3 Merged Tournaments and Special Prizes

Sometimes there are multiple championships merged in one tournament (e.g. chess). Such tournaments are, for example, men/women or different “under age” groups playing together. After the tournament is over the participants are divided in separate categories and separate standings are made. In **UnIdRaS** it is handled exactly in this manner with such tournaments – as multiple events, every one of them with its own *RF*.

On the other hand there are big open tournaments with special prizes available – for example, for best performing women, seniors, under age participants, amateurs. Winning such a prize brings prestige and is regarded in **UnIdRaS** as a *QP* (see 5.1). It is calculated according to

$$v = \frac{1}{P_s}, \quad (20)$$

where:

v – trophy (special prize) bonus,

P_s – position in the special prize group (e.g. 2nd special prize for women).

8.4 Ranking of Rankings

In most cases rankings⁴⁹ are not suitable to be treated as competitions. To illustrate this let's take the monthly published FIDE Rankings. As of July, 2013, there are 162 842 international chess players in the list. If we treat this ranking as a competition, the Number 1, Magnus Carlsen, will get unthinkable amount of points every time the ranking list is published, without doing anything.

Let's consider another example – the WFCC chess composition rankings existing since 1914. If this rankings are considered as competitions, the all times best, Petko Petkov, will get a lot of points every three years (the update period of the ranking), but also, he will be getting those points after his death, eternally (as everyone else in the ranking), since the deceased chess composers remain in the ranking.

49 The terms “ranking” and “standings” may sometimes cause confusion. “Standings” exclusively means a ranked list of participants in a competition, based on their performance. “Ranking” is a term with a broader meaning, including its usage as a synonym of “standings”.

Here is another point to be made. The chess composers send chess problems for approval and get points for successful problems. Every three years all the approved problems in this period are collected in a so called FIDE Album and the chess composers are ranked by the points they got for that period. Exactly the rankings for the separate 3-year periods can perfectly be treated as competitions and included in **UnIdRaS**.

Some keywords which describe competition-like rankings: single-shot performance, one-time event, time limited. If the first two conditions are met then there is a work-around for time unlimited rankings. For example, the Pi World Ranking List includes everyone who memorized certain amount of digital places of the number Pi. Memorizing a few thousands digits and getting in the top of the list surely brings prestige. Such performance can be treated as a competition and the contest standings can be represented by a snapshot of the list at the time of the performance.

8.5 Incomplete Data

In real life it might happen that full competition data is not available due to subjective reasons or data loss. Tournament organizers may publish only the standings of the best performers or hide the scores of the participants with the intention not to embarrass the underachievers. In case of incomplete competition data a worst case scenario should be assumed. For example, if no standings are available, we assume that the participant finished on the last place (of course, there should be a proof that he/she took part in the competition).

Interpolation can be used to deal with partial data. Let's suppose the following scenario. After a competition only the results of the top M competitors are published, but every participant privately receives information about how many points he/she achieved (but no information about his/her position in the overall standings. In this case the following linear interpolation is made to determine the position which will be used for the participant in the **UnIdRaS** rankings:

$$P_x = P_2 - (P_2 - P_1) \frac{S - S_2}{S_1 - S_2}, \quad (21)$$

where:

P_x – interpolated position,

P_1 – upper bound of the area to be interpolated,

P_2 – lower bound of the area to be interpolated,

S – score of the competitor,

S_1 – score corresponding to P_1 ,

S_2 – score corresponding to P_2 .

The lower bound of the area that needs to be interpolated is usually unknown. If no other data is available for making a better assumption, the lower bound is assumed to be the last position in the competition standings with a zero score.

Example

A competition with 12 participants. Known are the standings of the first five:

1. Player A – 87 points

2. Player B – 72 points

3. Player C – 61 points

4. Player D – 54 points

5. Player E – 48 points

We want to know what is the interpolated position of a player with 22 points. We get

$$P_x = 12 - (12 - 5) \frac{22 - 0}{48 - 0} \approx 8.8^{th} \text{ place.}$$

Another ambiguous situation might be where no subunits for a given competition can be clearly identified. In such cases, if there is “enough diversity” in the competition, then we assume $DF = 1$. “Enough diversity” cannot be generally defined; it is judged for every case separately. For example, if in a town chess championship only chess players take part who play every day in the club, there is not enough diversity and the event should be considered as an internal one instead of local.

9. Introducing Titles

Titles are related to enormous prestige gains and are widely acknowledged. The most renowned titles are in the academic circles (Professor, Doctor, etc.). In sports the best-known titles are of chess players (Grandmaster, International Master, etc.). In **UnIdRaS** titles are introduced to distinguish the best performing competitors.

While the values of the parameters in **UnIdRaS** can be edited and so the quantity of the points received in competitions, the titles offer a universal way for comparison across all eventual modifications of **UnIdRaS**.

The necessary points for awarding a title with respect to the default **UnIdRaS** parameters are given in Table 10.

<i>Norm</i>	<i>Title</i>	<i>Full Title</i>
1000	SC	Supreme Competitor
500	OC	Outstanding Competitor
250	DC	Distinguished Competitor
125	AC	Advanced Competitor

*Table 10: Norms for acquiring **UnIdRaS** titles*

The practical meaning, for example, of the first norm is that to acquire the highest **UnIdRaS** title – Supreme Competitor, one has to reach URS points equivalent to becoming first in a basic ($DF = 1.0$) national competition ($BR = 8$) with 125 participants (default values for the other parameters: $DR = 1.0$, $RF = 1.0$, $QP = 1$, $EB = 0$).

If a custom ranking is made and the values of the parameters in **UnIdRaS** are changed, then the norms for the titles have to be rescaled. For example, if in a custom ranking only competitions with a national rank or higher are included, then it is reasonable to set BR for the national events to 1. In this case the points needed for the titles should be divided by 8.

IV. Design of the UnIdRaS Software

For the gradual creation of the architecture of the **UnIdRaS** software the procedure described by Posch et al. (2007, p.59) was followed. The stages suggested by them are shown on Figure 9. We can differentiate three main phases:

1. Preparations for the architecture design.
2. Design, documentation and evaluation.
3. Implementation of the architecture.

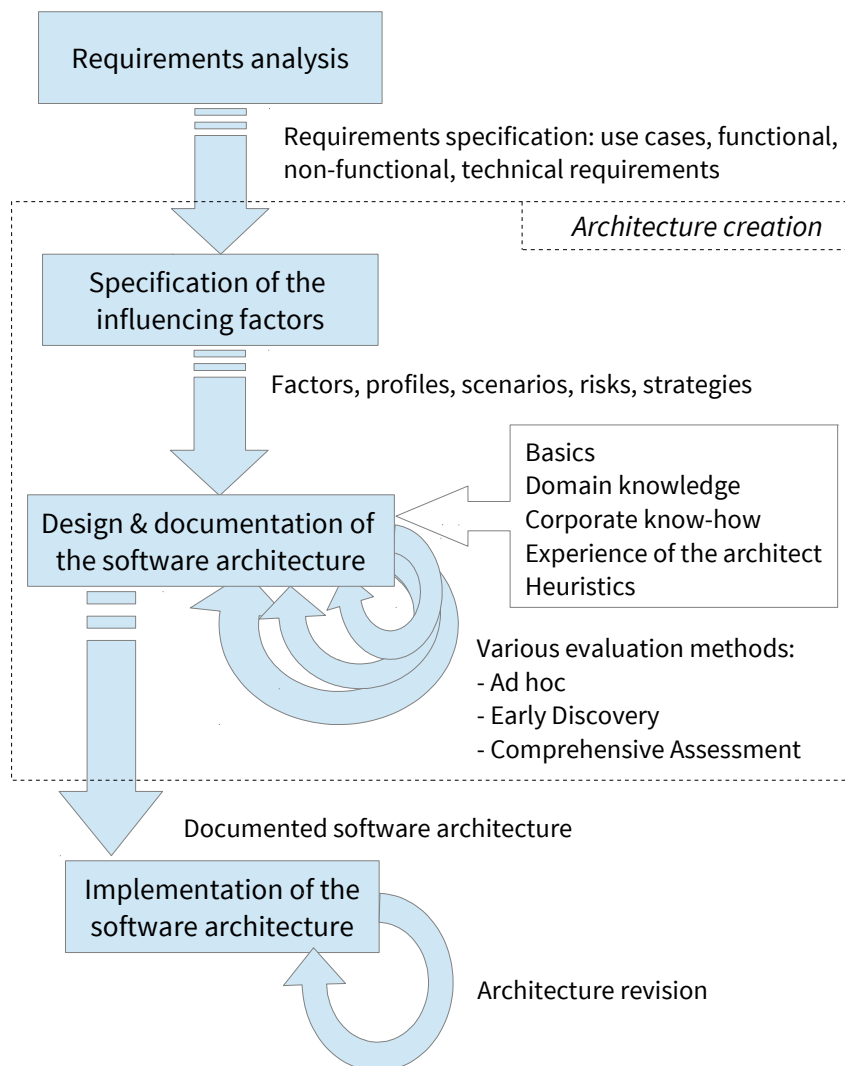


Figure 9: Creating the software architecture step by step

In the first phase the requirements analysis was performed to identify important input data for the architecture. The second step was the actual design of the architecture and its documenting. The last stage involves the implementation of the software architecture, which is a part of Chapter VI.

1. System Context

The creation of the ranking software is not an end in itself. It will not exist isolated from the environment. The ranking software will be operating under certain conditions which have to be considered during the development.

1.1 Purpose of the **UnIdRaS** Ranking Software

The **UnIdRaS** ranking software has the aim to fully implement the **UnIdRaS** ranking system and to make possible its practical use for generating universal interdisciplinary rankings in all kinds of competition areas. In this chapter the **UnIdRaS** software will be fully designed, describing also features that will be available in future versions. However, the constraints on the project (as being a master thesis) allow only critical features to be implemented in the prototype version.

1.2 Users of the Ranking Software

Sports clubs, schools or other organizations which take part in competitive activities can benefit from the **UnIdRaS** ranking software, having a tool for determining in a scientific way the contribution of their competitors to the organization's prestige. A further application of the ranking software can be in assistance the distribution of funds between different (sports) organizations, because it makes the universal interdisciplinary comparison possible.

The **UnIdRaS** ranking software will be used by the chess club “Tryavna-2001”, generating rankings of its chess player, which will be published on the club's website⁵⁰. The budget for the chess club is granted by the municipality, mostly based on the performance of the chess players in competitions during the previous year. The budget is limited and not all costs of the chess players' participation in tournaments can be covered. The generated **UnIdRaS** rankings will clearly show who has contributed most to the prestige of the club (and to the finance resources received from the municipality) and therefore who deserves to be sent to participate in more tournaments.

At the Technical University of Gabrovo, Bulgaria, is the second concrete application possibility. The new **UnIdRaS** ranking system, after approval, can replace the current prestige gain ranking system used for the generating the TUGab Index rankings.

50 The club is located in Tryavna, Bulgaria and its website is: www.tryavna2001.org.

2. Requirements

The software requirements are divided in the following three categories:

- A) Functional – determine what the system should do;
- B) Non-functional – determine the properties that the system should have;
- C) Technical – requirements that may impose technical limitations.

Each requirement has the following attributes: ID number, description, justification, fit criterion and priority. The “justification” describes why the feature is needed; the “fit criterion” defines the conditions that need to be fulfilled in order the implementation to be accepted. The “priority” of the requirements shows their importance and is divided into 5 categories:

- 1. **Critical** – defines an essential feature without the fulfillment of which the whole software system will not be accepted;
- 2. **Important** – specifies a feature of high priority;
- 3. **Significant** – the implementation of such a feature will contribute much to the whole system;
- 4. **Optional** – designates features which will have some small benefits to the system;
- 5. **Future** – fulfilling these requirements will require some fundamental changes in the software.

2.1 Functional Requirements

<i>ID</i>	FR01
<i>Description</i>	Applicability to all areas where a performance ordered list can be created.
<i>Justification</i>	One of the main ideas of the UnIdRaS ranking system is to be universal and interdisciplinary.
<i>Fit Criterion</i>	The universality and interdisciplinarity of the system is inherent, coming from its mathematical design. The software should implement all features granted by the mathematical concept, so that not only known competition formats are supported but all unconsidered at the time of design.
<i>Priority</i>	Critical

<i>ID</i>	FR02
<i>Description</i>	A direct interdisciplinary comparison.
<i>Justification</i>	This is a main goal of the system.
<i>Fit Criterion</i>	The UnIdRaS Prestige Rating (UPR) serves for a universal comparison. The software should extract the needed data from the database, calculate the UPR ratings and generate rankings.
<i>Priority</i>	Critical

<i>ID</i>	FR03
<i>Description</i>	Generation of various ranking lists.
<i>Justification</i>	The users should be able to filter the rankings according to their wishes.
<i>Fit Criterion</i>	The software should be able to filter the rankings by person, organization, competition field and time period.
<i>Priority</i>	Important

<i>ID</i>	FR04
<i>Description</i>	Input of partial standings.
<i>Justification</i>	Sometimes the full competition standings are not needed or not available.
<i>Fit Criterion</i>	The input and evaluation of partial data should be supported.
<i>Priority</i>	Important

<i>ID</i>	FR05
<i>Description</i>	Use of multiple parameter profiles.
<i>Justification</i>	The possibility to save and load sets of UnIdRaS parameters will make it easy to compare rankings generated with different values of the parameters, which may eventually lead to their optimization.
<i>Fit Criterion</i>	The software should support the easy saving and loading of different sets of parameters, which will be used at the time of rankings generation.
<i>Priority</i>	Significant

<i>ID</i>	FR06
<i>Description</i>	Use of multiple databases.
<i>Justification</i>	The user may want to administer different areas with different values for the parameters. In such a case it is meaningful to separate the areas.
<i>Fit Criterion</i>	The user should be able to choose which database is to be worked with.
<i>Priority</i>	Significant

<i>ID</i>	FR07
<i>Description</i>	Exportability of the rankings.
<i>Justification</i>	This feature is very useful for publishing the generated rankings.
<i>Fit Criterion</i>	At least one of these export formats should be supported: pdf, xls, html.
<i>Priority</i>	Significant

<i>ID</i>	FR08
<i>Description</i>	Total Prestige Gain calculator.
<i>Justification</i>	Users may be curious how many rating points they can get from a competition having a certain performance.
<i>Fit Criterion</i>	Users should be able to enter the competition data of a hypothetical competition and their performance and get the points prestige they gain.
<i>Priority</i>	Optional

<i>ID</i>	FR09
<i>Description</i>	Interpolation of missing standings data.
<i>Justification</i>	In some rare cases not all of the standings data is available. Nevertheless it should be still possible to include the competition in the rankings after interpolation based on secondary data.
<i>Fit Criterion</i>	It should be possible to enter competition data without the positions, which will be automatically interpolated based on other data like competition scores.
<i>Priority</i>	Optional

<i>ID</i>	FR10
<i>Description</i>	Storing detailed information about the competitions.
<i>Justification</i>	Detailed information about the competitions should be available for statistical purposes or in order to satisfy the users' curiosity.
<i>Fit Criterion</i>	The following information for every competition should be saved: name of the event, begin and end date, competition field, venue, organizer, standings including multiple tiebreak criteria, website, comments.
<i>Priority</i>	Optional

<i>ID</i>	FR11
<i>Description</i>	Online ranking service.
<i>Justification</i>	An online ranking service can be accessible from everywhere and enable the collaboration of users at different locations.
<i>Fit Criterion</i>	The users should have the possibility to manage online their own rankings through a website.
<i>Priority</i>	Future

2.2 Non-Functional Requirements

<i>ID</i>	NFR01
<i>Description</i>	English as system language.
<i>Justification</i>	The ranking software will be accessible to most people.
<i>Fit Criterion</i>	The user interface and the documentation have to be in English.
<i>Priority</i>	Critical

<i>ID</i>	NFR02
<i>Description</i>	Fair distribution of ranking points.
<i>Justification</i>	The players who achieve big successes should not be overtaken by competitors with just a lot of participation in competitions.
<i>Fit Criterion</i>	The feature is inherent by mathematical design. It depends mainly on the competitors' positions in the standings. Their input should be unambiguous, supporting place sharing.
<i>Priority</i>	Important

<i>ID</i>	NFR03
<i>Description</i>	Stimulation of further participation in competitions.
<i>Justification</i>	One of the aims of the ranking system is to motivate for participation in competitions.
<i>Fit Criterion</i>	The feature is inherent by mathematical design – a participation in competition always brings new points for the rating of the competitor. The rankings should be presented in an easily readable/comprehensible format.
<i>Priority</i>	Important

<i>ID</i>	NFR04
<i>Description</i>	Difference between the competitions' ranks.
<i>Justification</i>	A success in an international tournament is not the same as being successful in a local tournament. The differentiation of the tournament ranks is crucial for the fairness of the ranking system.
<i>Fit Criterion</i>	The system supports competition ranks by mathematical design, depending on a few parameters. The users should be able to enter these parameter easily and understandably, having their meaning clearly explained.
<i>Priority</i>	Important

<i>ID</i>	NFR05
<i>Description</i>	Different user roles.
<i>Justification</i>	Security reasons imply that not everyone should be able to edit the data.
<i>Fit Criterion</i>	The software should support at least two user types – an administrator, who can browse, enter, modify and delete data; and a guest, who can only browse the data.
<i>Priority</i>	Optional

<i>ID</i>	NFR06
<i>Description</i>	Team-mode input.
<i>Justification</i>	The team competitions are converted to individual ones before being used in the rankings.
<i>Fit Criterion</i>	The user should be able to easily input team competition data which is to be automatically converted.
<i>Priority</i>	Optional

<i>ID</i>	NFR07
<i>Description</i>	Multilanguage support.
<i>Justification</i>	Accessibility for people who doesn't speak English.
<i>Fit Criterion</i>	The user interface and the documentation should be available in other languages than English.
<i>Priority</i>	Optional

2.3 Technical Requirements

<i>ID</i>	TR01
<i>Description</i>	The ranking software should run on the Windows operating system.
<i>Justification</i>	The Windows OS family is most spread among the users.
<i>Fit Criterion</i>	The ranking system should be tested at least on Windows 7.
<i>Priority</i>	Critical

<i>ID</i>	TR02
<i>Description</i>	A Linux version of the software.
<i>Justification</i>	The sector of free operation systems should also be covered.
<i>Fit Criterion</i>	A version of the software should be tested on Ubuntu.
<i>Priority</i>	Future

<i>ID</i>	TR03
<i>Description</i>	An online-based version of the software.
<i>Justification</i>	An online version will make the software accessible from any locations with Internet access.
<i>Fit Criterion</i>	Such a version should be developed to run on a server and be accessible through a website.
<i>Priority</i>	Future

3. Use Cases

The use cases define the interactions between the actors and the system.

Actors

Guest – an unregistered user of the system. He is allowed only to generate rankings and to see them in a basic mode – without seeing or editing the parameters.

Contributor – a registered user of the system. He is allowed to see and generate rankings in advanced mode (seeing the specific parameters). He is allowed to export rankings. He can also add new competitions which are first shown as disabled and need to be approved by an *Administrator* in order to be used in the rankings.

Premium User – a registered user of the system, upgraded from a *Contributor* after a specific number of contributions. The *Premium User* can in addition to the *Contributor* generate rankings using custom values of the ranking parameters.

Administrator – he has full rights. He can generate and browse rankings in advanced mode and export them. He can add, edit, erase, enable and disable competitions. He can also edit the values of the specific parameters.

GUI – the graphical user interface which is the point for the user interaction.

Database Unit – prepares and executes the requests for the database, and delivers the data from the database.

Calculation Unit – processes the competition data and calculates the ratings.

The use cases are displayed on Figures 10, 11 and 12 and explained after that (cf. Belev, 2013, pp. 12-14)

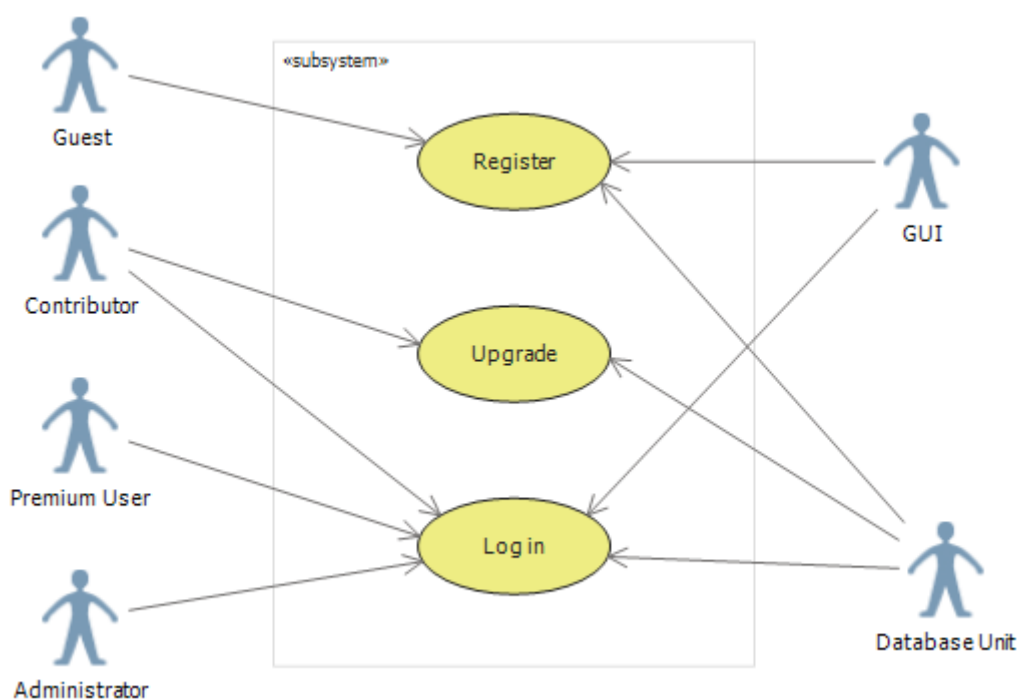


Figure 10: User-oriented use cases

Use Case 1: Register

The unregistered user (*Guest*) can register himself in the system and in this way become a *Contributor*, which will grant him the rights to browse the rankings in advanced mode, export them, and add new competitions (which are due to approval by an *Administrator*). New *Administrators* cannot be created direct in the system.

Use Case 2: Upgrade

After making a definite number of contributions (adding a certain number of approved competitions) the *Contributor* can upgrade his account to a *Premium User* who has the right to set custom values for the ranking parameters.

Use Case 3: Login

The registered user (*Contributor*, *Premium User* or *Administrator*) needs to log in, in order to use his full privileges. After the log-in more options will become available on the user interface.

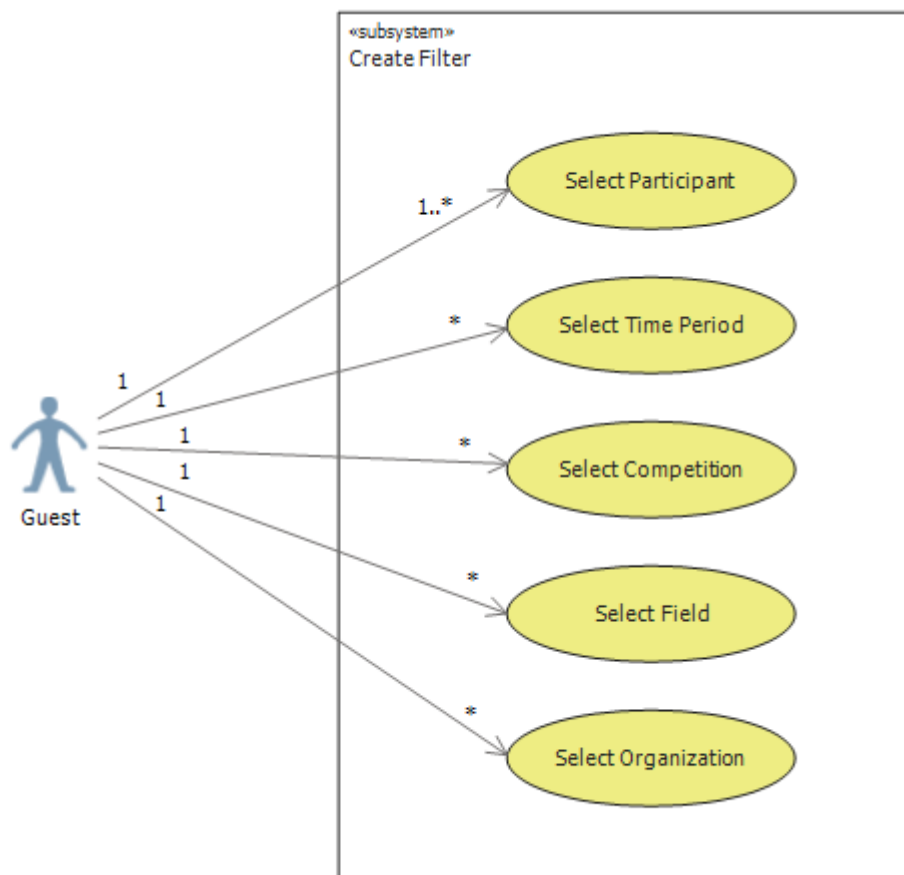


Figure 11: Filter-oriented use cases

Use Case 4: Create Filter

The ranking system takes into account all approved competitions, which can be an enormous variety. This is the reason for the existence of many filter options which limit the choice of competitions to only those which the user is interested in.

Use Case 4.1: Select Participant

One or more competitors can be chosen for whom the rankings to be generated.

Use Case 4.2: Select Time Period

A ranking can be generated for a chosen time period. In the ranking will be included only competitions which have their end date within this time period.

Use Case 4.3: Select Competition

A ranking can be generated also for manually selected competitions.

Use Case 4.4: Select Field

It can be chosen that a ranking is generated only for a certain competition field (e.g. informatics, chess, etc.)

Use Case 4.5: Select Organization

It is possible that players take part in competitions in the name of different organizations. This option is used for filtering the competition data by organization.

Use Case 5: Generate Ranking

After a filter (or none) is selected a ranking can be generated fetching competition data from the databank and feeding it to the calculation unit.

Use Case 6: Export Ranking

The registered users have the possibility to export the generated rankings.

Use Case 7: Add Competition

The registered users can add new data into the system. The competitions added by *Contributors* and *Premium Users* are with initial status “disabled” and are discarded when generating rankings. An *Administrator* can enable these competitions after his approval.

Use Case 8: Enable, Disable, Delete Competition

The *Administrators* have the rights to enable and disable competitions, which means that the competitions data will be included or discarded when generating rankings. Also only *Administrators* can delete data.

Use Case 9: Modify Competition

It is always possible wrong or containing errors data to be added. The *Administrators* have the right to edit the data in the system.

Use Case 10: Change Parameters

There are global parameters which influence the calculation of the rankings. These parameters can be changed by *Premium Users* and *Administrators*.

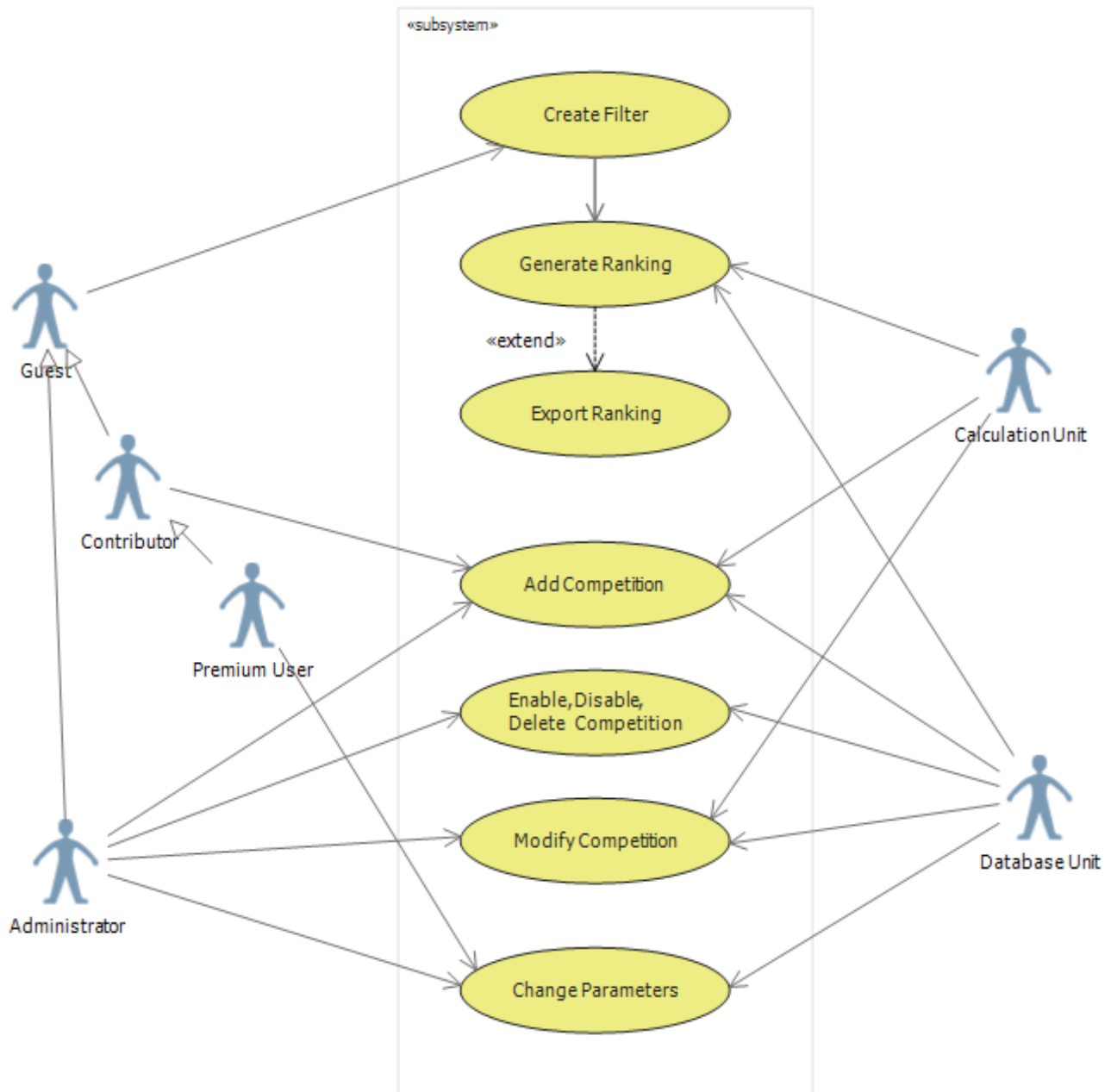


Figure 12: Competition-oriented use cases

4. Analytical Model

Figure 13 presents the main modules of the ranking system (Belev, 2013, p. 16).

GUI – the graphical user interface is the place for interaction between the user and the system.

Control Unit – the main logic that coordinates the actions and distributes the tasks to the other modules.

Calculation Unit – calculates the rankings as well as some parameters after the input of new competition data.

User Management – takes care for the users and the rights they have.

Database Access – serves as an interface to the databank, preparing requests and fetching data.

Databases – contain all the data about the competitions and the users.

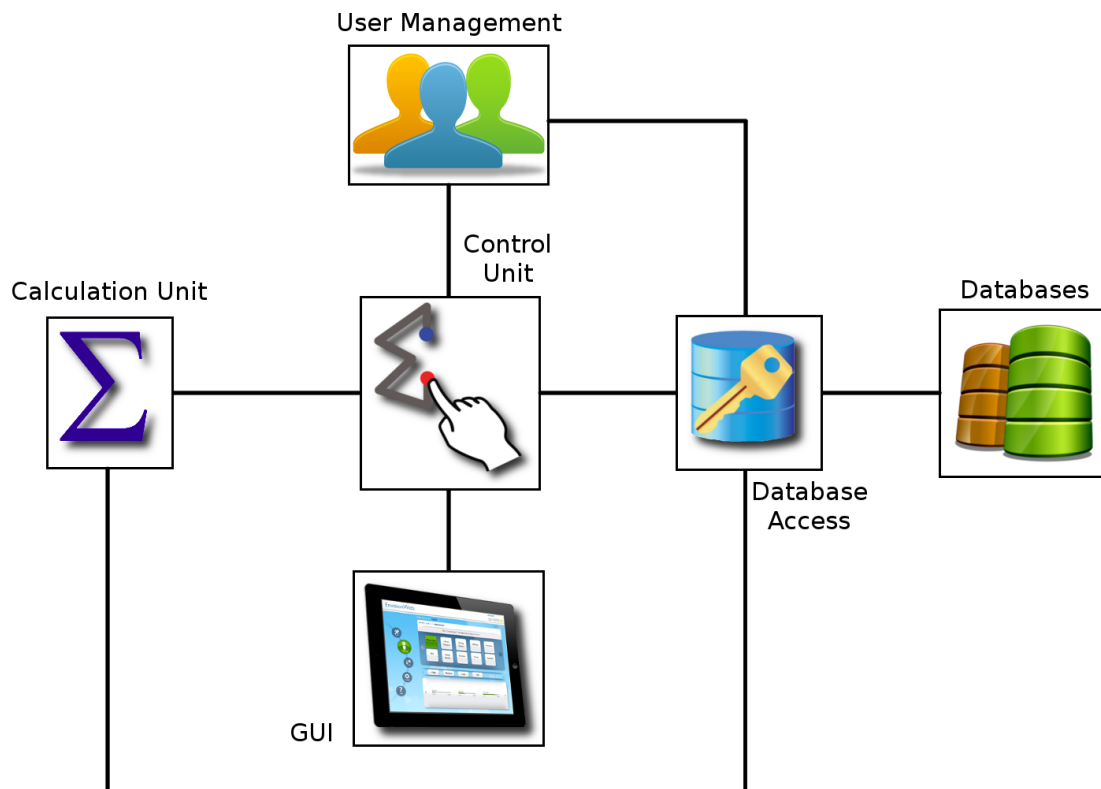


Figure 13: Structure of the *UnIdRaS* ranking software

5. Development of the Software Architecture

The first phase is to identify factors that influence the architecture. A list is made as a systematic compilation of all influences on the system. It helps in the assessment and prioritization of requirements. The influences are summarized in factor tables. It is proceeded with the identification of possible risks and development of potential strategies for solutions. This helps in selecting concepts for a first design and is also used to assess project risks. The risks and solution strategies are presented on thematic cards.

In the second phase the software is designed and its documentation created. This phase starts with further collection of input data and examination of the system context. The description of the viewpoints, together with the factors, risks and strategies constitute the core knowledge of the project. As architecture views are regarded the context, structural and behavioral views. UML component, structure and sequence diagrams are created to document the architecture.

The third phase is the evaluation of the architecture design. This is done by means of a comprehensive assessment.

The design of the software architecture is one of the three major design tasks of this master thesis. The other two are the design of the ranking system in a mathematical point of view (done in the previous chapter) and the design of the database (done in the next chapter).

5.1 Specification of Influencing Factors

There are three important groups of factors that can influence the software architecture: organizational, product and technological. The identification and analysis of all these groups of factors is important, because in this way it is proceeded with the design in a goal-oriented manner, which makes sure that the developed architecture can fulfill the system requirements.

5.1.1 Identification of Influencing Factors

Organizational Factors	Flexibility and Changeability	Influence on
O1: Management		
O1.1: Number of Collaborators		
The whole project has to be realized by only one person.	The project specifics don't allow other persons to take part.	Schedule, Design

01.2: Flexible Work Schedule		
There is no fixed work time during the day or throughout the week.	It offers great flexibility of the schedule.	Schedule
01.3: No External Customer		
The tasks and the requirements are defined internally.	Communication and misunderstanding problems are excluded.	Schedule
02: Schedule		
02.1: Fixed Schedule		
The project deadline is strictly fixed.	There is null tolerance in the schedule. A submission after the deadline makes the project invalid.	Design
02.2: No Time Estimation		
No time estimation for the whole project can be made because of lack of experience.	The development time for the separate parts of the project can change itself dramatically.	Design
03: Budget		
03.1: Hardware Costs		
The ranking software does not require any special hardware. It runs on every hardware system.	There will be no cost in the future.	Management
03.2: Development Costs		
No funds are available for the development.	For the first version of the software no financial resources are needed.	Design
03.3 Service Costs		
For the first version of the software there are no service costs.	When the ranking system has an online version, then costs for web hosting and domain name will come into account.	Management
04: Collaborators		
04.1: Domain-Specific Knowledge		
The collaborator has comprehensive knowledge in the fields of rankings and competitions.	No external consultation with a specialist is needed.	Management, Schedule
04.2: Lack of Database Design Knowledge		

The collaborator has very little knowledge in this field.	Gaining missing knowledge is critical and to be organized by oneself.	Schedule, Quality
O4.3: Programming Languages		
The collaborator has experience with C# and very little with Java.	Gaining extra knowledge is not possible because of the strict time schedule.	Schedule, Design

Product Factors	Flexibility and Changeability	Influence on
P1: Functional Requirements		
P1.1: Flexible Rankings		
The database design is very important because the software should offer a broad spectrum of rankings and competition statistics.	After the test phase there might be changes in the ranking system, setting different values for some parameters. These changes should not affect the competition data already entered in the database.	Database design
P1.2: User Roles		
Different user roles are important because of security reasons. However in an offline version of the software this is not critical.	In the online version of the software user roles become essential. This should be considered in database design.	Software and database design
P2: Portability		
P2.1: Other Platforms		
The software should be ported to other operation systems.	In the future the software should be ported at least to Linux.	Design
P2.2: Other Technologies		
The software will have an online version, which will be created using other technologies.	A loose coupling of the user interface will ease the development of a future online version of the software.	Design

Technological Factors	Flexibility and Changeability	Influence on
T1: Software Technologies		
T1.1: Development Environment		

Because of Factor O3 (Budget) only available or free software tools have to be used.	Because of Factor O4.3 (Programming languages) C# and Visual Studio will be used for the development.	Implementation
T1.2: Operating System		
The software runs on the Windows-family operating systems.	Later the software will be ported to Linux too.	Implementation
T1.3: Database Management System		
A free solution is needed.	The MySQL DBMS is to be used.	Implementation

5.1.2 Identification of Risks

Two main risks were identified:

Non-adherence to the schedule – the deadline for the project is fixed and cannot be changed. Any noncompliance with it will be fatal. Multiple collaborators at the project are not permitted and therefore no parallel work can be done. The situation is worsened by the collaborator's lack of knowledge in database design.

Changeability and flexibility of the system – the ranking software must be designed and implemented to allow future changes and adjustments in the values of the parameters, without modifying the existing competition data.

5.1.3 Strategies for Solutions

Non-Adherence to the Schedule
<p>The ranking software system has to be developed in a strictly definite period of time. Factors like limited number of collaborators and lack of specific knowledge worsen the situation.</p> <p>Influencing Factors:</p> <p><i>O1.1: Number of Collaborators</i></p> <p><i>O2: Schedule</i></p> <p><i>O4.2: Lack of Database Design Knowledge</i></p>
<p>Solution: The development time should be shortened through use of various strategies.</p> <p>Strategy: <i>Prioritization</i></p> <p>The development should be concentrated on the critical requirements. All other features should be left for the future versions if needed.</p>

Strategy: *Use of Known Development Tools*

Known and productive development tools should be used by the collaborator, so that no time is needed for learning new software products.

Strategy: *Database Crash Course*

The missing knowledge in database design has to be acquired in the shortest possible time by the developer.

Related Issues and Strategies

Budget (O3): No funds are available for purchasing software, training etc.

Flexible Rankings (P1.1): The system has to be designed and implemented with regard to future development.

Changeability and Flexibility of the System

The ranking software system has to allow changes in the parameters without a great effort and any influence on the already stored competition data. The system has to be designed to support a future porting to other platforms.

Influencing Factors:

P1.1: Flexible Rankings

P2: Portability

P3: User interface

Solution: The system can be divided into relatively independent parts in order to enhance the changeability and flexibility.

Strategy: *Central Storage of the Parameters*

The parameters needed for the calculation of the rankings, for which a change of the default value is possible, can have values defined as categories. Each competition will point to one of the categories and the assigned values to each category will be stored centrally in the database. So, one can adjust the values for the separate categories without correcting the competition data. If the dynamic calculation of the ratings leads to unacceptably long response times, caching mechanisms have to be considered.

Strategy: *Loose Coupling of the User Interface*

For creating the user interface, Windows Presentation Foundation (WPF) will be used. For porting the system to Linux (to other platforms is also possible), the .NET-compatible development and run-time environment "Mono" will be used. It does not support WPF, so the user interface should be loose coupled to simplify the porting.

Related Issues and Strategies

Schedule (O2): There is a strictly fixed deadline.

5.2 Design and Documentation

The software architecture is viewed from different perspectives and described using UML diagrams.

5.2.1 Context View

The user and the database management system are the two systems the ranking software exchanges data with. They constitute the environment of the ranking software. The user orders all the tasks to be done and the databases contain all the data. The whole scheme can be seen on Figure 14 (Belev, 2013, p. 23).

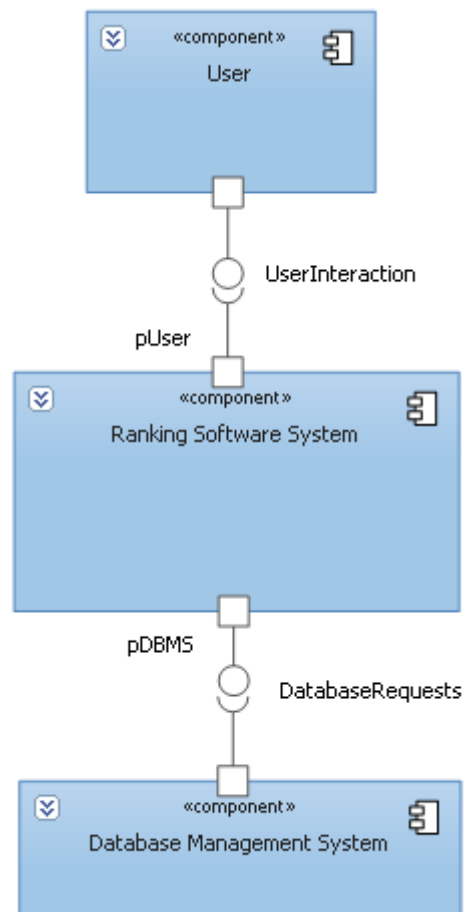


Figure 14: Context view of the architecture

5.2.2 Structural View

The components of the ranking software system can be seen on Figure 15 (Belev, 2013, p. 24). They provide an encapsulation of the main tasks of the system.

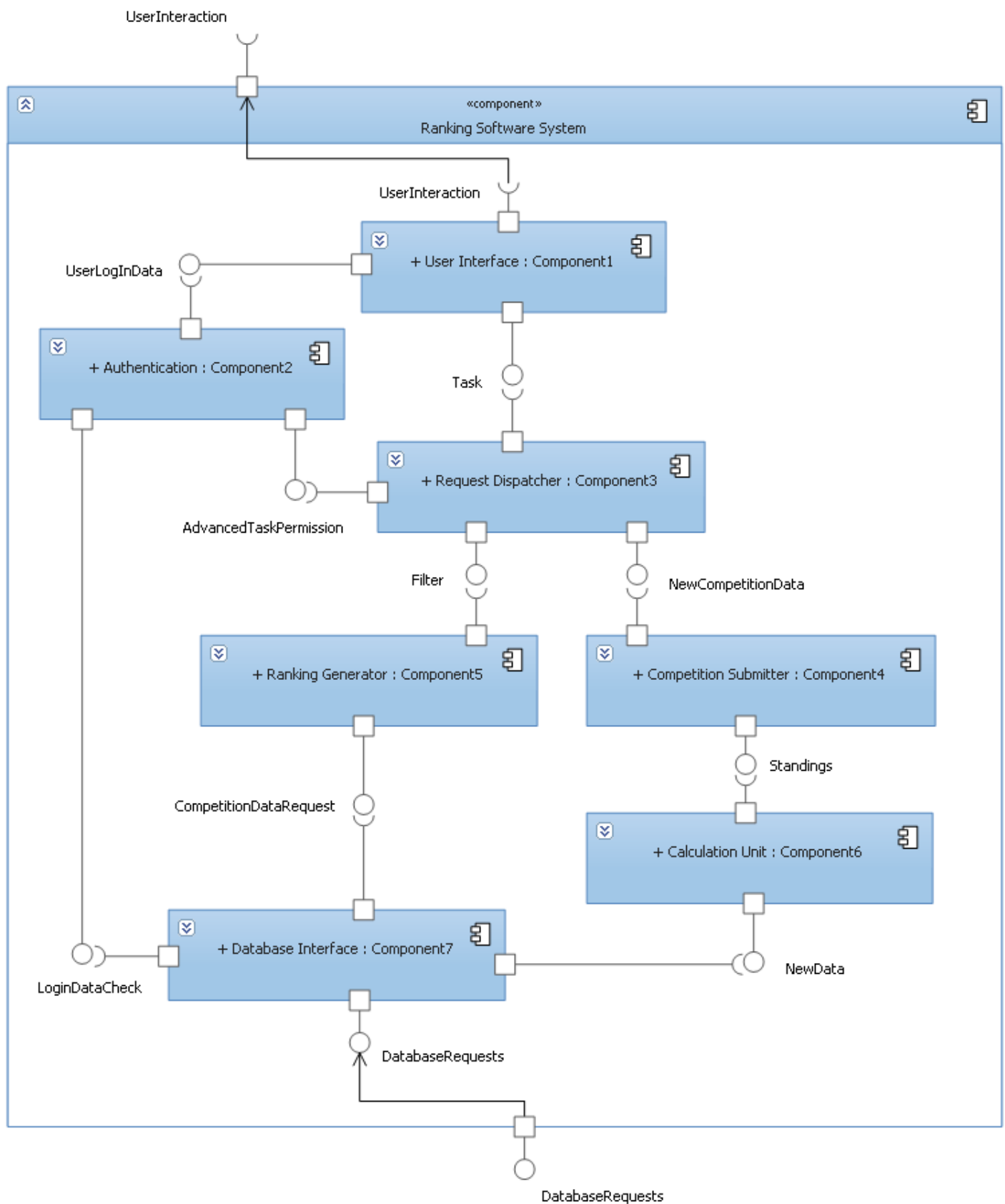


Figure 15: Structural view of the architecture

5.2.3 Behavioral View

The main dynamic processes in the system are shown on Figure 16 (cf. Belev, 2013, p.25). It can be seen which components in which actions take part.

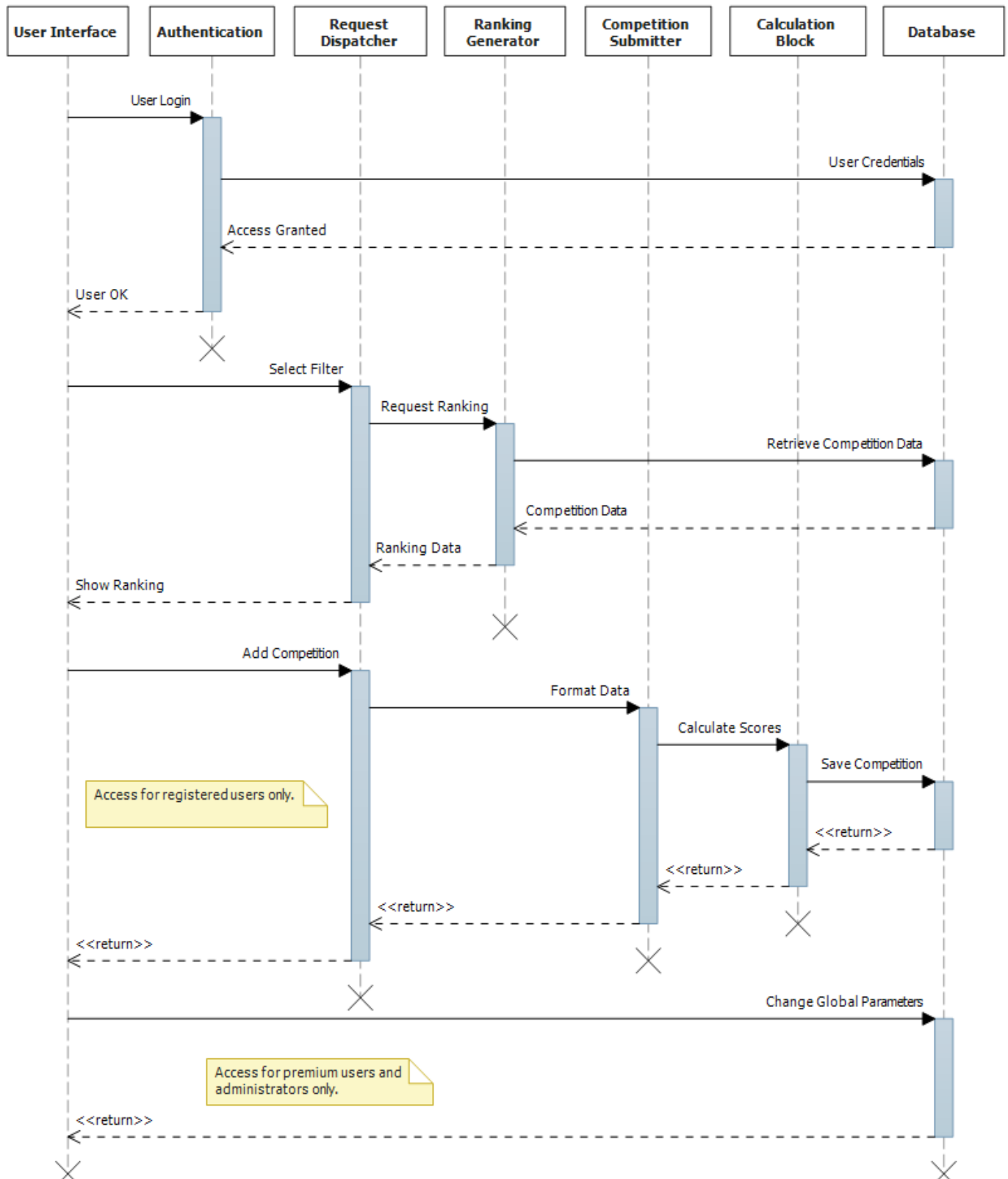


Figure 16: Behavioral view of the architecture

5.3 Comprehensive Assessment – the ATAM Method

The comprehensive assessment is an important step which aims to verify the accuracy of the architecture before its implementation. The Architecture Tradeoff Analysis Method (ATAM) is a method for evaluation of software architectures, which exposes architectural risks that may potentially inhibit the goals of the organization.

ATAM has 4 phases but the middle two are the core of the method. They are divided into 9 steps. In the first three steps the ATAM method, the business drivers and the architecture are presented. In step 4 architectural approaches are identified. In the ranking software's architecture the following two architectural approaches are present:

- (a) Use of the layered architectural style in the non-strict form, where the architecture consists of loosely coupled horizontal layers. The data flow in the ranking software begins with the user, goes through the processing layer and reaches the data layer. This architectural style makes the porting of the software easier.
- (b) The Template Method Design Pattern is used when new competition data is entered. It offers flexibility when the algorithm for processing of the data needs to be adapted to the input data.

In step 5 of the ATAM method a utility tree is built, which is another way to present the influencing factors. The first level of the tree are the most important factors that affect the architecture. The second level are categories of the factors. The last level are the scenarios with their priorities. The scenarios are relative to one another, prioritized in two dimensions with high (H), medium (M) and low (L). The first dimension shows how important is the scenario for the success of the whole system and the second one indicates how difficult it is to implement that scenario in the system (Posch 2007, p. 191). On Figure 17 a utility tree is built for the ranking software.

In step 6 the architectural approaches are analyzed. Here all important leaves of the tree are examined. Leaves with "L" are not treated and those with "M" only if there is time. To the leaves are assigned the architectural approaches, which contribute to the solution of the corresponding aspects. Here are the ones for the ranking system:

- (a) The *Flexible Ranking* depends mainly on the user interface and the database interface layer which converts the applied filter into database requests.
- (b) The *Portability* to other platforms or technologies is supported by the loose coupling of the interface.

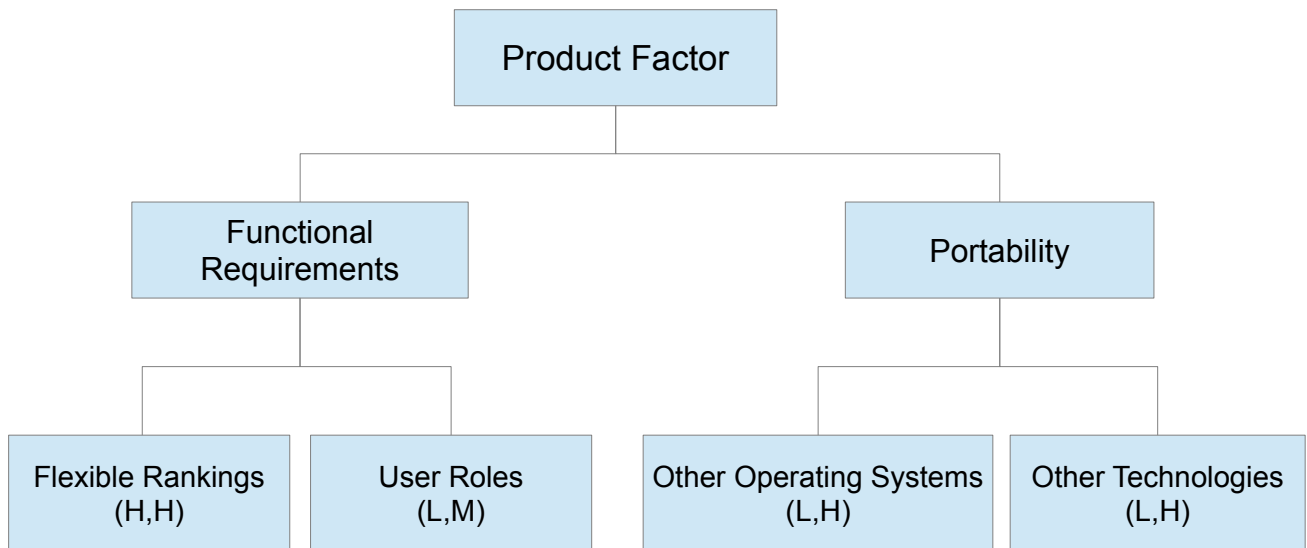


Figure 17: A utility tree for the ranking software system

As a sensitivity point can be identified the *Database Interface* component, because it is responsible for the proper requests to the database, which is critical.

Steps 7-9 are the stakeholder-centered evaluation of the architecture. In this phase the results from the previous steps are verified.

6. Implementation of the architecture

After the architecture has been designed the phase of its actual implementation begins. This has been done during the development of the prototype of the ranking software, which is described in Chapter VI. However, as occasionally happens, some changes have been made to the architecture during the implementation phase. Also other aspects haven't been taken into account because of the limitations of the software prototype. But before that the **UnIdRaS** database had been designed and implemented. It is an essential component in the whole system, which has been also taken into consideration during the design of the software architecture.

V. Design and Implementation of the UnIdRaS Database

The design of the database, holding all the information about the competitions, is of essential importance for the UnIdRaS ranking system. A good design can ensure that the ranking software will faultlessly fulfill its purpose. The development process goes through different stages, starting with the initial problem statement, continuing through the making of a model, then designing the software, and finally creating the application (see Figure 18).

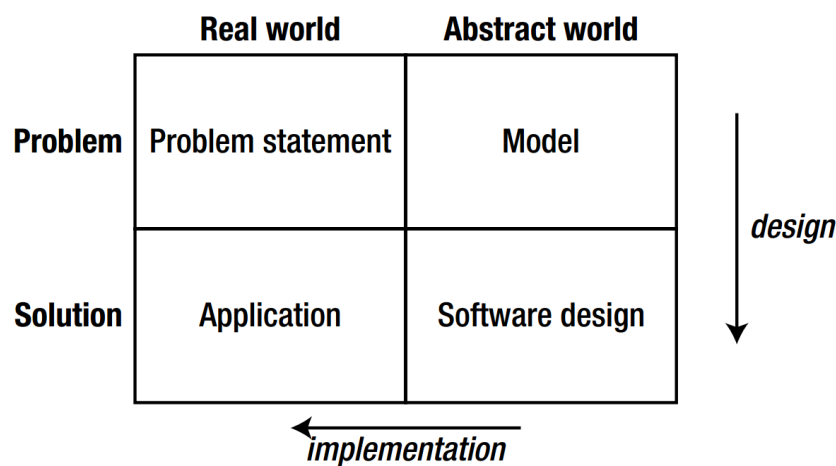


Figure 18: The software process (Churcher, 2012, p. 10)

1. Real and Abstract View of the Problem

The whole process begins with an initial description of the problem. Appropriate for this purpose are the use cases, describing how the user might interact with the system.

The UnIdRaS database will be mainly used in two different ways (see Figure 19):

Use case 1 – Entering new competition data;

Use case 2 – Reporting on competitors & competitions.

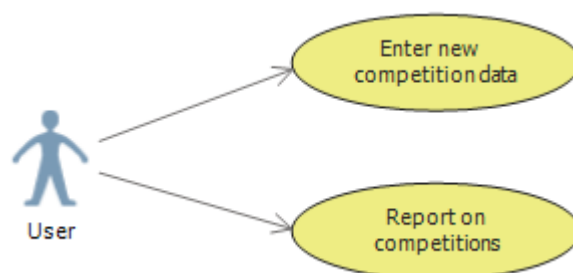


Figure 19: Main uses of the ranking system

The two use cases for the ranking database correspond to the two typical ways of data processing for this kind of database problems:

- Entering, editing, i.e. maintaining data;
- Extracting information from the database based on some criteria.

So, there are two things that should be done: to understand what tasks need to be carried out by all the people who will use the system, and then figure out what data needs to be stored to support them. The abstract model is presented on Figure 20.

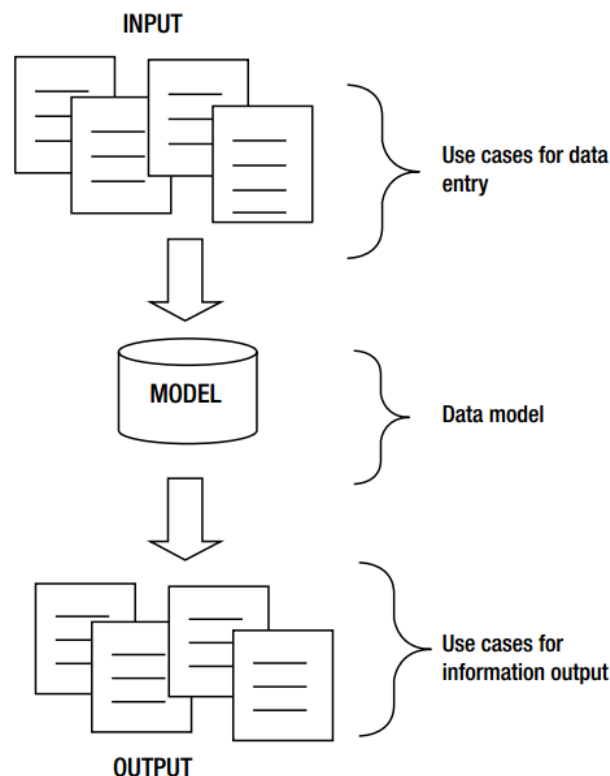


Figure 20: A typical database system (Churcher, 2012, p. 27)

2. Initial Requirements and Use Cases

After we have an initial idea of the design direction, the data model needs to be formed. For that purpose we need to understand some basic concepts.

2.1 Classes, Objects and Relations

A class is a template for storing data about a set of similar things. For example, a candidate for a class in the ranking system is “Competition”. The pieces of information, that will be kept about each class, are referred to as attributes of the class. There may be processes (operations) that a class would be responsible for carrying out. For example, a process for calculating the rating of a competitor.

An object of a class has its own value for each attribute. An example for attributes for the class “Competition” may be: name of the competition, date of the competition, number of participants, scores of the participants, etc. (see Figure 21).

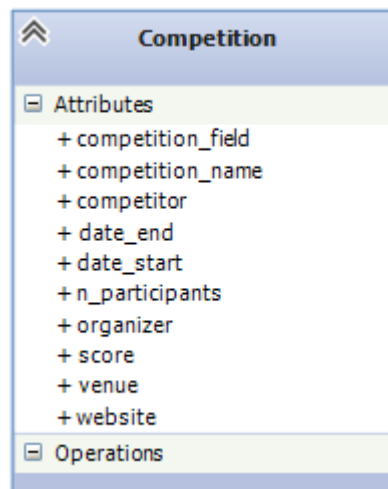


Figure 21: Sample class "Competition"

And a relation is an association between particular objects. On Figure 22 we see the relation between two classes – “Competitor” and “Competition”. The pair of numbers near the line indicates how many objects of one class can be associated with a particular object of the other class. They are referred to as multiplicity (or cardinality) of the relationship. The first number is the minimum number, which is usually 0 or 1 and therefore is also called optionality (i.e. indicates whether there must be a related object). The second number is the greatest number of related objects which is usually 1 or many (denoted “*” or *n*). The nearest pair of numbers to a class indicates how many objects of that class can be associated with the one object of the other class. Typical options are 1, 0..1, 1..*n*, *n*.

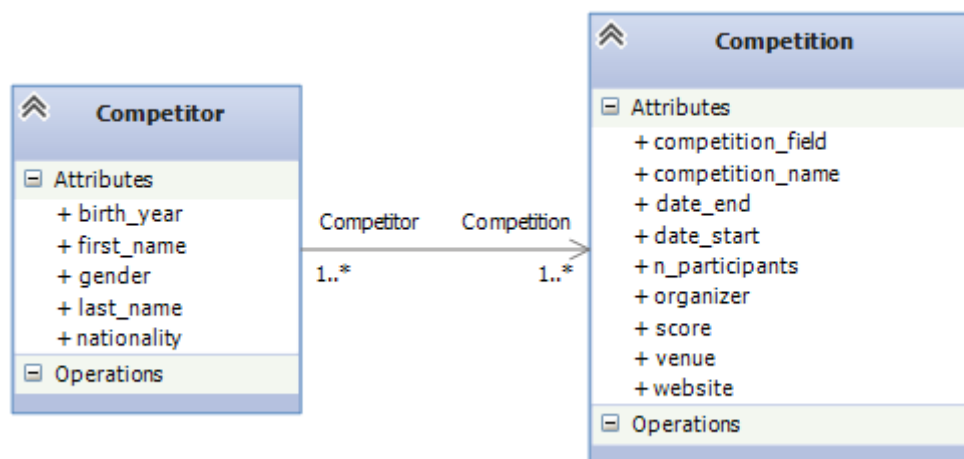


Figure 22: A relation between two classes.

2.2 Data Inconsistencies

A purpose of the abstract model is to concept the database so that no data inconsistencies may occur. Such inconsistencies may appear, because of redundant data, multiple routes for retrieving the same data, false information from a route, or gaps in the route between classes. In Table 11 (the data is not real) an example for repeated data is given.

competition_id	name	venue	n_participants	competitor	▲	score
1	7th Vama Open	Vama, Bulgaria	87	Boris Chatalbashev		7.00
2	7th Vama Open	Vama, Bulgaria	87	Dimitar Mladenov		3.00
3	7th Vama Open	Vama, Bulgaria	87	Kiril Hristov		3.00
4	7th Vama Open	Vama, Bulgaria	87	Stefan Ivanov		1.00

Table 11: Repeated data in a database

We see that for every participant the attributes of the competition (name, venue, number of participants) are the same. Such database should be maintained very carefully, because entering wrong data for the competition attributes leads to data inconsistencies, which will bear wrong or incomplete results in the reports. This shows that every piece of data should exist only once in the database. Problems with redundant data can be solved with introduction of new classes, in this case a “Competition” and a “Competitor” class.

2.3 Input Data

We can generally divide the **UnIdRaS** database data in two groups. One is data needed for the calculation of the ratings (mandatory data), which is the main purpose of the **UnIdRaS** Software, and the second one is additional (optional) data, which serves to give more information to the users.

2.3.1 Calculation data

The needed parameters for the calculation of the ratings can be determined from Chapter III. These parameters can be global or specific. In the first group are parameters that are valid for all the competitions in the database, and the second are parameters that are competition-specific. The global parameters are given in Table 12 and the specific – in Table 13. These parameters are atomic, i.e. cannot be calculated from other parameters. The user have to enter them in the system. The only exception is the Bonus Base (B) parameter which is inherent for the system and is set to 100. The user is not allowed to change it. That's why the parameter won't be present in the database. It is listed in Table 12 only for information.

<i>Global Parameters</i>	
DR	Discipline Recognition
BR	Base Rank
RF	Restrictions Factor
<i>B</i>	<i>Bonus Base</i> ⁵¹
DW	Data Window
SD	Step of Devaluation

Table 12: List of the global parameters

<i>Specific Parameters</i>	
N	Number of all participants
U	Number of subunits
M	Number of participants from the largest subunit
P	Normalized position in the standings
V	Rewarded individual or team position, or special prize place
W	Normalized team position
Z	Size of the world Top Z elite list
L	List of the world ranks of participants from the Top Z list

Table 13: List of the specific parameters

2.3.2 Additional Data

The additional data is optional and can be omitted without any considerable consequences for the system. However its existence will contribute to the completeness of the system. In Table 14 are given such parameters.

<i>Additional Parameters</i>	
<i>About a competitor</i>	<i>About a competition</i>
Name(s)	Name
Alternative name(s)	Alternative name
Sex	Competition field
Birth year	Start & end dates
Nationality	Venue
Organization	Organizer

Table 14: Additional parameters in the database

51 The Bonus Base parameter belongs to the core of the system and shouldn't be changeable by the user.

2.4 Output Data Use Cases

For data retrieval and reporting tasks we should look for attributes that might be used for sorting, grouping, or selecting data. These attributes may be candidates for additional classes.

The **UnIdRaS** Prestige Rating (UPR) parameter is to be used for sorting the competitors and generating the rankings. If this was the only way of using the database it would be easy – just saving the UPR for every competitor and updating the value after each new competition. But the database should be designed to offer various rankings, filtered by competition field, time period, organization and any combination of them. For example:

Generate the rankings...

... for the current year.

... only for competitions in the field of mathematics.

... only for competitors from the Hochschule Mittweida.

... for the competitors from the chess club “Tryavna-2001” who have taken part in chess competitions in 2012.

This need of flexibility necessitates that the Total Prestige Gains (TPG) from every competition are stored for every competitor. And when a ranking request is filed then all the TPG from the competitions in consideration are summed and multiplied by the time devaluation function in order to form the UPR. If this procedure tends to be too slow then some caching mechanisms can be implemented – like precalculating the values for the most used queries.

However there is another requirement – to be possible to change the global parameters. This necessitates storing all specific parameters and when a change in the global parameters occurs, TPG for all competitions in the database has to be recalculated. In this “static mode” scenario all TPG values are precalculated and when a ranking request comes, the TPG values are simply read. This leads to a fast generation of rankings.

When the static mode may not be suitable? Let's assume that we have a large database of competitions and we want to make tests of the ranking system with different global parameters. Every change of the global parameters will lead to a total recalculation of all TPG values in the database. This might take a long time, even more if we want to make a lot of tests with different global parameters. The solution to this is to define a dynamic

mode of TPG calculation, where the TPG values are calculated on the fly using the atomic specific and global parameters. However in the calculation of TPG different mathematical functions take part, which may slow down the calculation significantly. Is it possible to optimize this mode? Yes, with the introduction of composite specific parameters, which are precalculated from the atomic specific parameters and don't depend on any global parameter.

If we analyze the formulas in Chapter III, we get the composite specific parameters (Table 15) and the composite global parameters (Table 16).

<i>Composite Specific Parameter</i>	<i>Dependencies</i>
Homogeneity (H)	Number of all participants (N) Number of participants from the largest subunit (M)
Diversity Factor (DF)	Homogeneity (H) Number of subunits (U)
Trophy bonus (v)	Rewarded individual or team position, or special prize place (V)
Team bonus (w)	Normalized team position (W)
Quality Premium (QP)	Trophy bonus (v) Team bonus (w)
Main Prestige (MP)	Normalized position in the standings (P) Number of all participants (N) Quality Premium (QP)
Competition Performance (CP)	Normalized position in the standings (P) Number of all participants (N)
Elite Level (EL)	Size of the Top Z list (Z) List of the world ranks of the Top Z participants (L)
Maximal Bonus (MB)	Number of all participants (N) <i>Bonus Base (B) [always fixed to 100]</i>
Elite Bonus (EB)	Competition Performance (CP) Elite Level (EL) Maximal Bonus (MB)
Success in Competition (SC)	Main Prestige (MP) Elite Bonus (EB)

Table 15: Composite specific parameters and their dependencies

Only the top composite specific parameters (marked with bold in Table 15) need to be stored in the database, i.e. those which contain only atomic or lower level composite specific parameters and which no other composite specific parameter depends on.

The composite global parameters are given in Table 16. Because of the dependencies (highlighted) on the atomic global parameters, they cannot be precalculated.

<i>Composite Global Parameter</i>	<i>Dependencies</i>
Event Rank (ER)	Diversity Factor (DF) Base Rank (BR) Restrictions Factor (RF)
Total Prestige Gain (PG)	Discipline Recognition (DR) Event Rank (ER) Success in Competition (SC)

Table 16: Composite global parameters and their dependencies

3. Initial Data Model

After the input and output use cases and parameters become relatively clear, it can be started with the building of the classes and the relations between them. The whole data model can be seen on Figure 23.

The “Competition” class contains the name of the competition and an alternative name (in a different language), a competition ID, the start and end dates of the competition (the second one will be used in relation to the time devaluation function), the venue, and the organizer. The “tag” attribute that can be used for special selection purposes. The “extra_info” attribute is meant for additional information (e.g. the competition's website). The attribute “complete_standings” shows if full results are available, or the standings contain only partial data – for some of the positions. The attribute “is_disabled” indicates if the competition should be excluded from the rankings (for example if it is still not approved or there is a problem with the reliability of the competition data).

The “CompetitionField” class is a separate class and not an attribute in “Competition” to prevent generating multiple competition fields which differ only in spelling and actually are one and the same. Every competition must be associated with a competition field. Events which feature multiple disciplines (e.g. pentathlon) should be put in new categories. At least one competition has to be associated with each competition field.

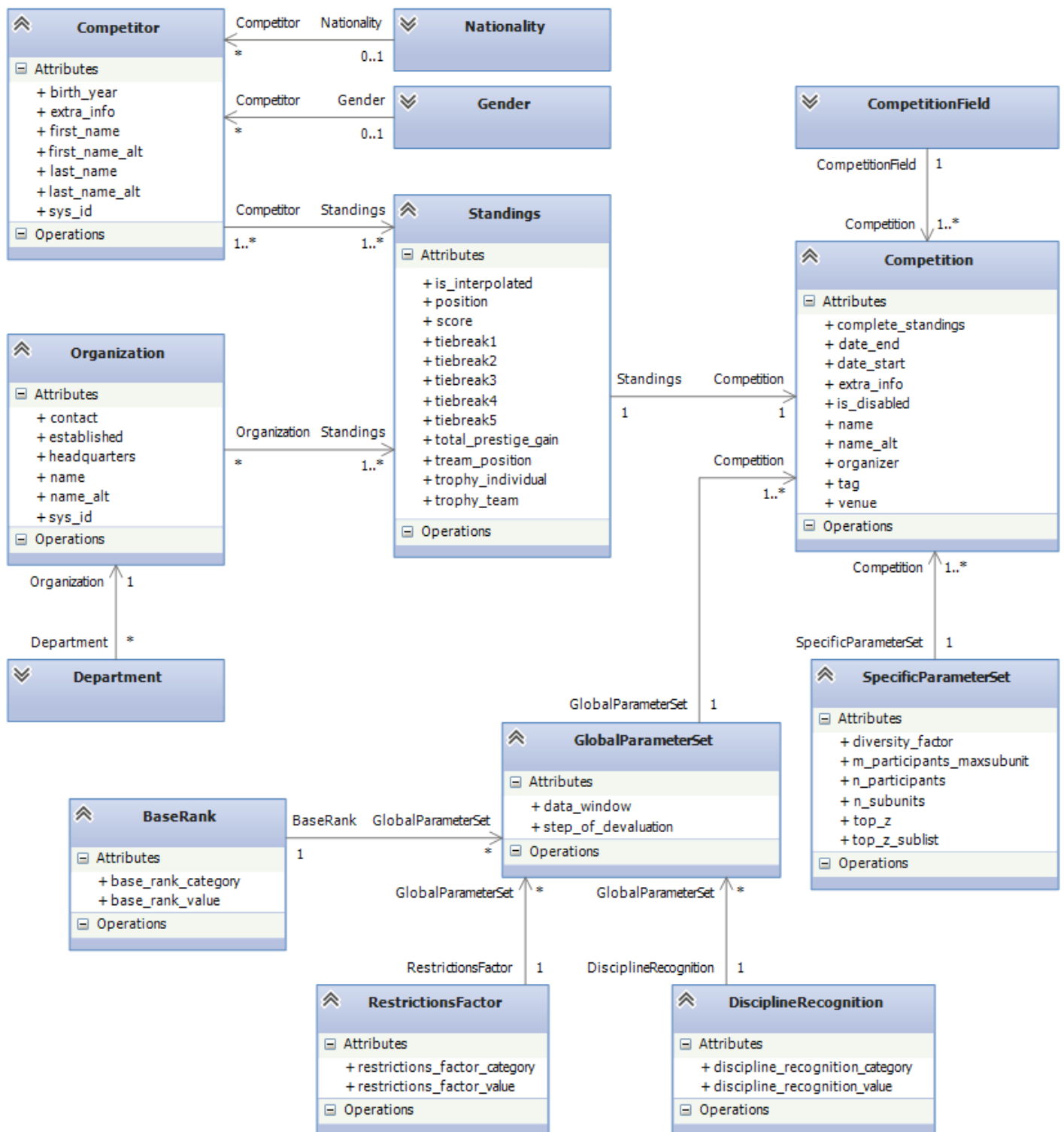


Figure 23: Initial data model of UnIdRaS

The “Standings” class has as attributes the results of a competition: the positions, the scores, five tiebreak criteria. Also the parameter Total Prestige Gain, the indicators for a team or individual trophy, as well as a team position. The attribute “is_interpolated” indicates an interpolated result. The relationship between a standings object and a competition object is one to one.

The “Competitor” class contains the data for a competitor: names and alternative names, birth year and additional information. A unique identification number is assigned to each competitor. It can be used for an alternative way to search for a competitor in the database. At least one competitor object needs to be associated with a standings one, and vice versa. This means the competitors must have taken part in at least one competition, and there is no competition without any participants.

The “Nationality” class represents the (main) country of the competitor. The relation to the “Competitor” class is optional (the nationality of the competitor may be unknown). Zero or more competitor may have a certain nationality.

The “Gender” class is analogous to the “Nationality” class, but showing if the competitor is male or female.

The “Organization” class has attributes describing an organization from the name of which a competitor takes part in a competition: name and alternative name, main location, year of establishment, contact data. Each organization has a unique identifier like each competitor. Zero or more organizations can be associated with one standings object, and at least one standings object must be associated with a particular organization.

The “Department” class is associated with the “Organization”. One organization can have many departments, and to every department is associated only one organization.

The “SpecialParameterSet” class contains the atomic and composite parameters: Diversity Factor, number of participants, number of subunits, number of participants from the largest subunit, number of elite positions, a list with the world ranks of participants from the Top Z ranking. The relation to a competition is one to one.

The “GlobalParameterSet” contains the global parameters data window and step of devaluation, which are the same for all competitions. To every competition must be associated exactly one global parameter set, and to one global parameter set can be associated one or more competitions.

Three classes with predefined categories are associated to the “GlobalParameterSet” class: “BaseRank”, “RestrictionsFactor” and “DisciplineRecognition”. Each object of the “GlobalParameterSet” must be associated with exactly one object of the other three classes. Many objects of the “GlobalParameterSet” class can be associated with particular objects of these three classes.

4. Normalization

Normalization is the process of organizing the fields and tables (of a relational database) to minimize redundancy and dependency. There are several normal forms and each of them is free of a certain set of anomalies. The normal forms are accumulative, for example, a table which is in the Third Normal Form (3NF) is also in the Second (2NF) and First (1NF) Normal Forms.

4.1. Anomalies

Why should we normalize the databases? Let's consider the example given in Table 17 (the data is not real).

id	competitor	gender	club	tournament	venue	n_participants	score
1	Boris Chatalbashev	M	Chess-XXI	7th Varna Open	Varna, Bulgaria	87	7.00
2	Dimitar Mladenov	M	Topalov-2000	Albena 2012	Albena, Bulgaria	215	3.50
3	Vanya Hristova	F	Kaisa	7th Varna Open	Varna, Bulgaria	87	3.00
4	Stefan Ivanov	M	Seagulls	7th Varna Open	Varna, Bulgaria	87	1.00
5	Vanya Hristova	F	Kaisa	Albena 2012	Albena, Bulgaria	215	5.00

Table 17: Non-normalized table

An update anomaly can be caused by redundant data. This data inconsistency occurs after a partial update. For example, we want to change the venue of the 7th Varna Open tournament. After changing it in the first row, the data becomes immediately inconsistent because we'll have different venues for the same tournament (in row 1 opposed to rows 3 and 5).

A deletion anomaly is the unintended loss of data due to deletion of other data. For example, the club “Seagulls” ceases to exist and we delete it. But with its deletion the data of the competitor Stefan Ivanov will be gone too.

An insertion anomaly is the inability to add data due to absence of other data. For example, the field “gender” is set not to be null (every person has a gender). But what if we want to add the player Xie Chen and have no gender data available? To do so we need to guess his/her gender which is not the way to go.

All these anomalies are highly undesirable in the database, that is why normalization is applied in order to avoid them. Most 3NF tables are free of insertion, update, and deletion anomalies.

4.2 First Normal Form

A table is in 1NF if:

- a) There are no duplicated rows in the table (i.e. a primary key is defined);
- b) Each cell is single-valued (i.e. no multiple values are put in a single cell) and no multiple fields in a single table are used to store similar data.

The other requirements are usually guaranteed by the database management system (DBMS): entries in a column are of the same type, each attribute name must be unique, the order of the columns/rows is insignificant.

After analysis of the initial data model again, we find out that it is seriously flawed regarding the “Standings” class. This class, according to its name, should represent the whole standings in a competition (if so, the relation to the “Competition” class is correct). However, one object of the class represents only one position in the standings, unless the cells contain multiple values, which is against 1NF. So the class needs to be renamed to “Result” in order to correctly represent its role. Also, its relation to the “Competition” class has to be changed so that one or more results are needed to make a competition valid. The multiplicity to the “Competitor” class changes in a way that exactly one competitor is associated with each result. To each result can be associated one or zero organizations.

The tiebreaks 1 to 5 in the (already) “Result” class might seem an issues, but everything is all right with them, because they represent totally different things and are not multiple values of only one tiebreak.

But an issue to be fixed is the “top_z_sublist” which really contains multiple values – the Top Z world ranks of participating competitors. This attribute was converted into a class called “WorldRank”, multiple instances of which can be associated with a “SpecificParameterSet” object, and vice versa.

Another change is the conversion of the “Department” class (which has no real use) into “Membership” with attributes “enrollment” (the year when a competitor entered an organization) and “section” (in case the organization is subdivided).

Also a “TimeDevaluation” class was added to contain the time related parameters which are not directly related to the other parameters.

The improved data model is shown on Figure 24.

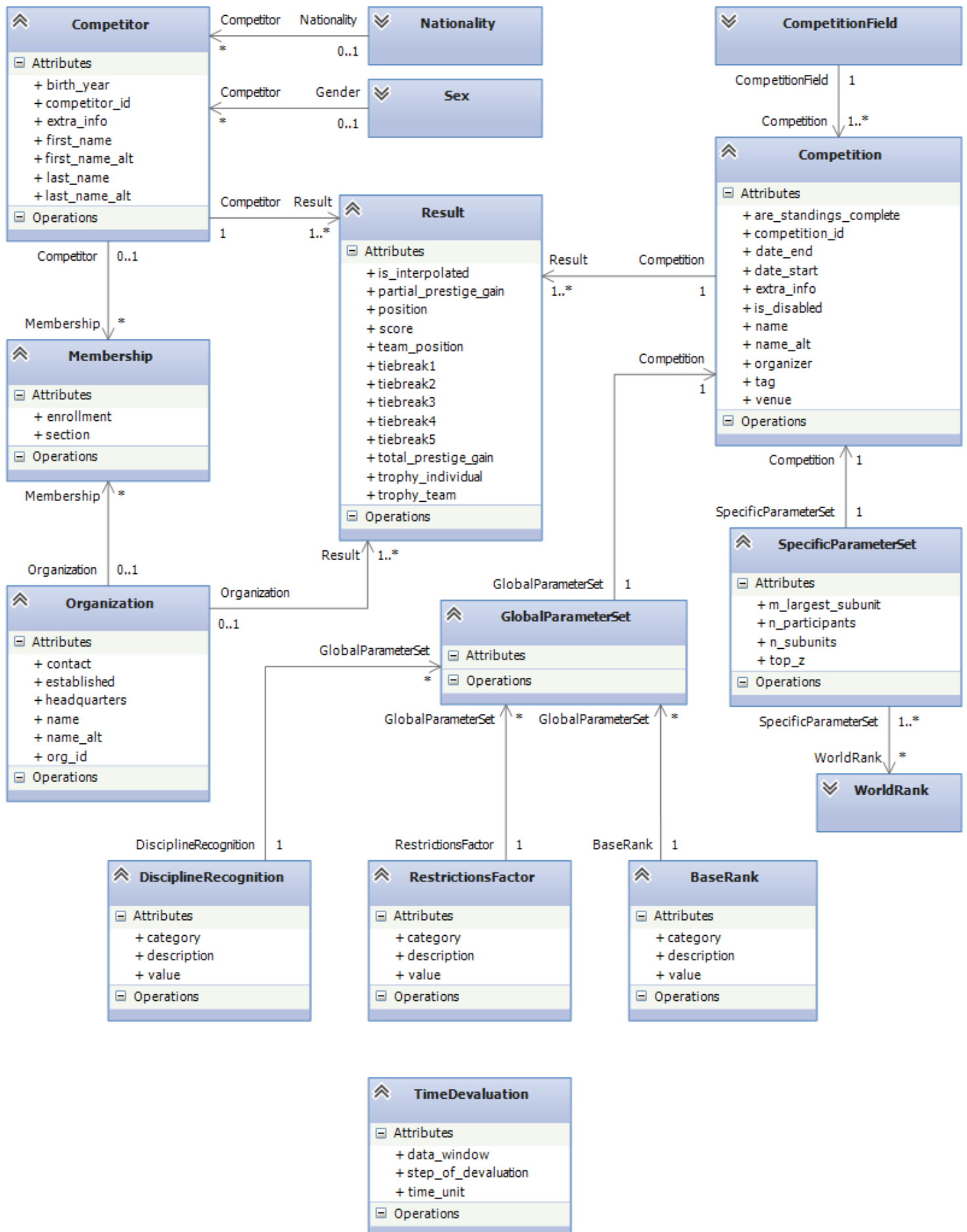


Figure 24: Improved data model

The no duplication of rows is guaranteed by the following keys:

- IDs in “Competitor”, Organization, “Competition”;
- Categories in “BaseRank”, “RestrictionsFactor”, “DisciplineRecognition”;
- Value in “Nationality”, “Sex”, “CompetitionField”.

For the tables “Result”, “GlobalParameterSet”, “SpecialParameterSet”, “WorldRank”, “TimeDevaluation” and “Membership” a surrogate primary key has to be introduced.

4.3 Second Normal Form

A table is in second normal form (2NF) if it is in 1NF and all of its non-key attributes are dependent on all parts of the key. Relations that have a single attribute for a key are automatically in 2NF. Exactly this is the case with all classes in the **UnIdRaS** data model.

4.4 Third Normal Form

A table is in 3NF if it is in 2NF and if it has no transitive dependencies. We have a transitive dependency if for the relation R containing attributes A, B and C is true that:

$A \rightarrow B$ and $B \rightarrow C$ and $A \rightarrow C$.

Another way to formulate the 3NF is: a table is in Third Normal Form if it is in 2NF and no non-key fields depend on a field(s) that is not the primary key.

For some of the classes in the **UnIdRaS** data model this is not fulfilled. For example, in the “Organization” class the name depends on the system ID, and the date of establishment of the organization depends on the name (assuming that no two organizations with the same name exist). Another example for transitive dependency is in the “Competition” class, where the name depends on the system ID, and the alternative name depends on the name.

However, although from a theoretical point of view it is recommended to normalize into the 3NF, it may not always be practical because it may degrade performance. It is recommended to apply 3NF only on data that changes frequently⁵². The **UnIdRaS** database contains exclusively historical data, which doesn't tend to change over the time. For this reason it was decided not to 3NF-normalize the few classes that are not in 3NF.

52 support.microsoft.com/kb/283878 (accessed on 12-08-2013).

5. Implementation

The widely used open-source relational database management system, MySQL, was chosen for the implementation of the data model. It was proceeded as follows:

- For each class, a table was created;
- For each attribute, a field with an appropriate data type was created;
- Constrains were applied to some fields;
- Primary keys were set;
- Foreign keys were set;
- Indexes were created to speed up the searches.

A screenshot of the MySQL databank is shown on Figure 25.

Column Name	Datatype	PK	NN	UQ	BIN	UN	ZF	AI	Default
competition_id	INT(10)	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
name	VARCHAR(45)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
name_alt	VARCHAR(45)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	NULL
date_start	DATE	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
date_end	DATE	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
organizer	VARCHAR(45)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	NULL
venue	VARCHAR(45)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	NULL
tag	VARCHAR(45)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	NULL
are_standings_complete	TINYINT(1)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
is_disabled	TINYINT(1)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
extra_info	TEXT	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	NULL
field	VARCHAR(45)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	NULL
global_parameter_set	INT(11)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

Figure 25: Screenshot from MySQL Workbench

In the “Result” table a field called *partial_prestige_gain* has been introduced with an optimization purpose. It will store the product $DF.SC$, which is an intermediate calculation result, independent from the global parameters. Its purpose is to be used for calculation of the UPR in dynamic mode. In static mode the field *total_prestige_gain* is to be used.

VI. Prototypical Software Implementation

After taking into consideration the factors described in Chapter IV (especially 03.2 and 04.3) the programming language Visual C# has been chosen for the development of the ranking software. Microsoft Visual Studio Ultimate 2012 with .NET 4.5 has been chosen as development environment.

The presented here prototype of the **UnIdRaS** Ranking Software implements all essential features described in Chapter IV, as well as many other useful ones. However this is only a prototype (although fully functional) and there is room for further improvements.

The ranking software can be used in two ways – for entering new competition data (data input) and for generating rankings (data retrieval). The two options are shown on the welcome screen of the software (Figure 26).



Figure 26: Welcome screen of the ranking software

1. Data Input

One competition has many parameters that need to be specified. Some of them are mandatory and other are optional. The user is guided through three different windows (with an option to go back and forth using the tabs), in which he enters the competition data. All input data is due to verification. Based on the parameters entered by the user,

other parameters are also calculated. At the end the user has the option to save all the data in the databank. The whole process is shown on Figure 27.

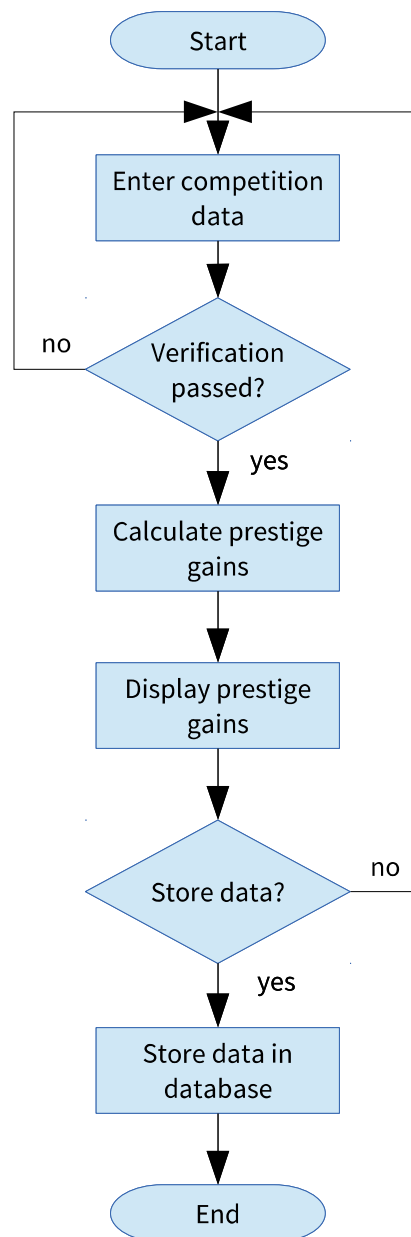


Figure 27: Algorithm for data input by the user

1.1 Input Data Verification

Two verification strategies are used. The first one is checking the data while the user is typing. This strategy is applied to the most important parameters and if the format or the value of the entered data is wrong then immediately a red border appears around the input box to signal that the data is incorrect. Tooltips give more information what kind of data should be entered.

The second strategy is full data verification before performing any calculations. This verification checks not only the format of the data but verifies if the values of the parameters make sense in relation to other entered parameter.

The general data that needs to be entered for a competition is shown on Figure 28. The name of the competition, the start and end dates, and the competition field are mandatory. The name cannot consist of only whitespace characters. The end date cannot be before the start date. The competition field can be chosen from a list of already existing fields in the database, or the user can enter a new one.

The screenshot shows a software window titled "Add New Competition" with three tabs: "Description", "Competition data", and "Standings". The "Competition data" tab is active. It contains the following fields:

- Name of competition:** IV Balkan amateur chess festival Belogradchik 2013
- Alternative name:** IV Балкански шахматен фестивал за любители
- Start date:** 19-Aug-13 (with a calendar icon)
- End date:** 25-Aug-13 (with a calendar icon)
- Field of competition:** Chess (selected from a dropdown menu)
- Location:** Belogradchik, Bulgaria
- Organizer:** Chess Club "Nayden Voynov"
- Info:** belchess.com

On the right side of the form, there is a logo for "UnIdRaS" featuring a large stylized Greek letter Sigma (Σ) with various numbers and a trophy. A "Next ->" button is located at the bottom right of the window.

Figure 28: General data about a competition

The second tab, shown on Figure 29, is dedicated to specific data. The categories of Discipline Recognition, Competition Rank and Restrictions are predefined. The user chooses them from the corresponding combo boxes. These predefined lists are loaded from the databank.

The values of *number of subunits* and *largest subunit* cannot be greater than the number of participants. These two parameters are disabled for internal competitions. Also if there is only one subunit then the *largest subunit* will equal *number of participants*.

If interpolation of missing positions has to be performed, then this option should be enabled and the boundaries specified. The lower bound position cannot be greater than the number of participants.

If players from the world elite take part, their ranks can be entered. No rank can exceed the size of the Top Z ranking list.

Add New Competition

Discipline Recognition: Sport A - Recognized by the International

Competition Rank: International (C)

Restrictions: Amateurs (Am)

Number of all participants: 120

Number of subunits: 12

Largest subunit: 80

☐ Enable interpolation of missing results

Interpolation parameters

	Position	Score
Upper bound participant:		
Lower bound participant:		

☐ Elite competition

Elite players

Size of the world elite list: 0

List of the ranks of the participating elite players:

Next ->

Figure 29: Specific parameters of a competition

In the third tab, shown on Figure 30, the user enters the competition standings. They don't need to be complete. They may contain only some of the positions, and also in a mixed order. *Position*, *Last Name* and *First Name* are obligatory fields. The latter two cannot consist of only whitespace characters. If the position is set to zero, then it will be interpolated (if the option is enabled) based on the score of the competitor. The score has to be strictly in the range specified by the interpolation parameters. It should be noted that *Position* and *Team Position* need to be in a normalized form. That is why they can have .5 values (and because of interpolation they may have any decimal value).

If the score and/or the tiebreaks are of type “less is better” (e.g. time) then they should be entered with a minus sign.

Sex and *Nationality*, if set, can take only specific values. For *Sex* – 'M' or 'F', and for *Nationality* – the three-letter country codes.

Position	Last Name	First Name	Sex	Nationality	Organization	Team Position	Individual Trophy	Team Trophy	Score	TB1	TB2	TB3	TB4	TB5
1.0	Player	A	F	LTU		0.0	0	0	100	3	0	0	0	0
2.0	Player	B	F	GER		0.0	0	0	94	0	0	0	0	0
3.0	Player	C	F	GER		0.0	0	0	94	1	0	0	0	0
4.0	Player	D	F	GER		0.0	0	0	92	1	0	0	0	0
5.0	Player	E	F	UKR		0.0	0	0	90	1	0	0	0	0
6.0	Player	F	F	GER		0.0	0	0	90	3	0	0	0	0
7.0	Player	G	F	ESP		0.0	0	0	89	1	0	0	0	0
8.0	Player	H	F	GER		0.0	0	0	89	1	0	0	0	0
9.0	Player	I	F	GER		0.0	0	0	88	1	0	0	0	0
10.0	Player	J	F	GER		0.0	0	0	87	3	0	0	0	0
11.0	Player	K	F	GER		0.0	0	0	85	1	0	0	0	0
12.0	Player	L	F	GER		0.0	0	0	84	1	0	0	0	0
13.0	Player	M	F	GER		0.0	0	0	84	2	0	0	0	0
14.0	Player	N	F	GER		0.0	0	0	83	0	0	0	0	0
15.0	Player	O	F	GER		0.0	0	0	83	0	0	0	0	0
16.0	Player	P	F	GER		0.0	0	0	82	0	0	0	0	0
17.0	Player	Q	F	GER		0.0	0	0	82	0	0	0	0	0

Buttons: Import CSV, Calculate Prestige Gains, Save in Database

Figure 30: Entering the competition standings

The user has also the possibility to import comfortably large data sets, stored as CSV files. The delimiter must be “;” and the text qualifier “ ”. The CSV file must contain the following column names: Position, LastName, FirstName, Sex, Nationality, Organization, TeamPosition, IndividualTrophy, TeamTrophy, Score, TB1, TB2, TB3, TB4 and TB5. For the CSV-Import feature a third-party library was used.

1.2 Calculation of Prestige Gains

The Total Prestige Gain of a competitor in a given competition can be calculated by a formula, which includes only parameters directly entered by the user. The formula is

$$TPG = DR \cdot BR \cdot RF \cdot \left(2 - \sqrt{\frac{2}{U}} \right) \cdot \left(N \cdot P^{\frac{\sqrt{V^{-1}} + \sqrt{W^{-1}} - 2}{2}} + \frac{N+1-P}{N} \cdot \frac{2 \sum_{k=1}^E (Z+1-R_k)}{N(2Z-N+1)} \cdot 100 \log_2 N \right), \quad (22)$$

where:

TPG – Total Prestige Gain,
DR – Discipline Recognition,
BR – Base Rank,

RF – Restrictions Factor,

U – number of subunits,

N – number of participants,

P – normalized position of the participant in the standings,

V – individual or team place for which a trophy or an award is received,

W – normalized position of the team in the team standings,

E – number of participating elite players,

Z – number of elite players in the world (in this discipline),

R – world rank of a participating elite player, $R \in [1, Z]$,

assuming that:

- Homogeneity (6) is less than or equal to 0.75,
- full Quality Premium (9) is received,
- the number of participants is less than the number of elite players in the world (16).

As it was discussed in point 2.4 from the previous chapter, it is reasonable to introduce a new component, called Partial Prestige Gain (PPG). It is calculated by

$$TPG = GP \cdot PPG, \quad (23)$$

where:

TPG – Total Prestige Gain,

GP – global parameters,

PPG – Partial Prestige Gain,

and

$$GP = DR \cdot BR \cdot RF, \quad (24)$$

where:

GP – global parameters,

DR – Discipline Recognition,

BR – Base Rank,

RF – Restrictions Factor.

PPG is for internal purposes only and won't be accessible for the user. It will serve in the future when an optimized recalculation of TPG is implemented. This is the so called

dynamic mode, which will allow the values of the global parameters to differ from the standard ones and to be changeable through the user interface.

In the prototype the standard static mode has been implemented. TPG is calculated at the time of entering the new competition data, after clicking the *Calculate Prestige Gains* or *Save in Database* buttons (Figure 31).

The screenshot shows a software window titled "Add New Competition" with three tabs: "Description", "Competition data", and "Standings". The "Competition data" tab is active, displaying a table with the following columns: Nationality, Organization, Team Position, Individual Trophy, Team Trophy, Score, TB1, TB2, TB3, TB4, TB5, Interpolated, and Total Prestige Gain. The table contains 18 rows of data. Below the table are three buttons: "Import CSV", "Calculate Prestige Gains" (which is highlighted with a blue dashed border), and "Save in Database".

xx	Nationality	Organization	Team Position	Individual Trophy	Team Trophy	Score	TB1	TB2	TB3	TB4	TB5	Interpolated	Total Prestige Gain
	LTU		0.0	0	0	100	3	0	0	0	0	<input type="checkbox"/>	844.800
	GER		0.0	0	0	94	0	0	0	0	0	<input type="checkbox"/>	422.400
	GER		0.0	0	0	94	1	0	0	0	0	<input type="checkbox"/>	281.600
	GER		0.0	0	0	92	1	0	0	0	0	<input type="checkbox"/>	211.200
	UKR		0.0	0	0	90	1	0	0	0	0	<input type="checkbox"/>	168.960
	GER		0.0	0	0	90	3	0	0	0	0	<input type="checkbox"/>	140.800
	ESP		0.0	0	0	89	1	0	0	0	0	<input type="checkbox"/>	120.686
	GER		0.0	0	0	89	1	0	0	0	0	<input type="checkbox"/>	105.600
	GER		0.0	0	0	88	1	0	0	0	0	<input type="checkbox"/>	93.867
	GER		0.0	0	0	87	3	0	0	0	0	<input type="checkbox"/>	84.480
	GER		0.0	0	0	85	1	0	0	0	0	<input type="checkbox"/>	76.800
	GER		0.0	0	0	84	1	0	0	0	0	<input type="checkbox"/>	70.400
	GER		0.0	0	0	84	2	0	0	0	0	<input type="checkbox"/>	64.985
	GER		0.0	0	0	83	0	0	0	0	0	<input type="checkbox"/>	60.343
	GER		0.0	0	0	83	0	0	0	0	0	<input type="checkbox"/>	56.320
	GER		0.0	0	0	82	0	0	0	0	0	<input type="checkbox"/>	52.800
	GER		0.0	0	0	82	0	0	0	0	0	<input type="checkbox"/>	49.694

Figure 31: Calculated prestige gains

The algorithm for calculation of TPG for all results in a competition is shown on Figure 32.

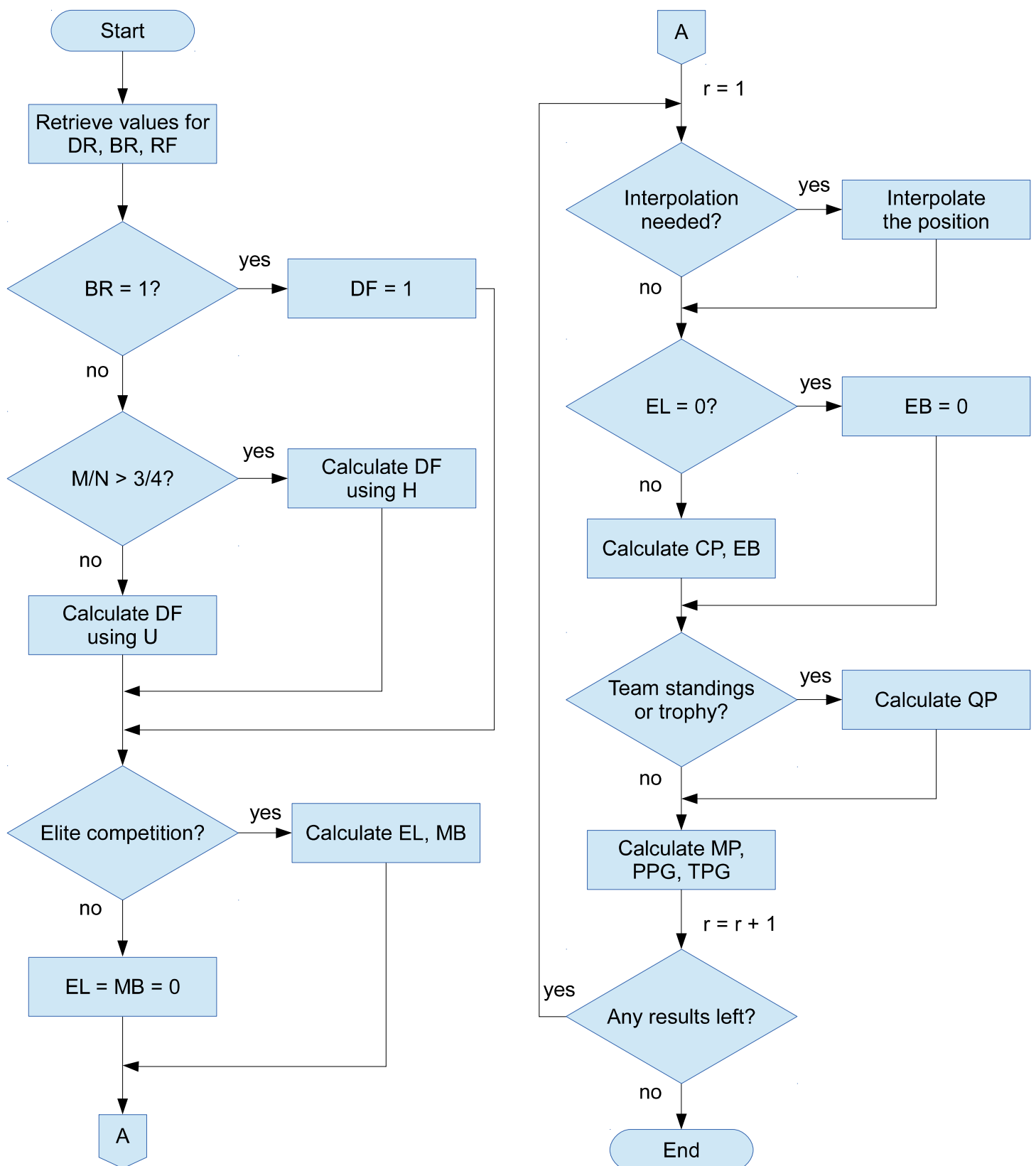


Figure 32: Algorithm for calculating TPG

1.3 Storing Competition Data in the Database

The data has to be inserted into the database in a definite sequence. Otherwise the data insertion will fail due to the constraints on the tables. The constraints enforce the table relations described in the previous chapter. The algorithm for data insertion is shown on Figures 33a & 33b.

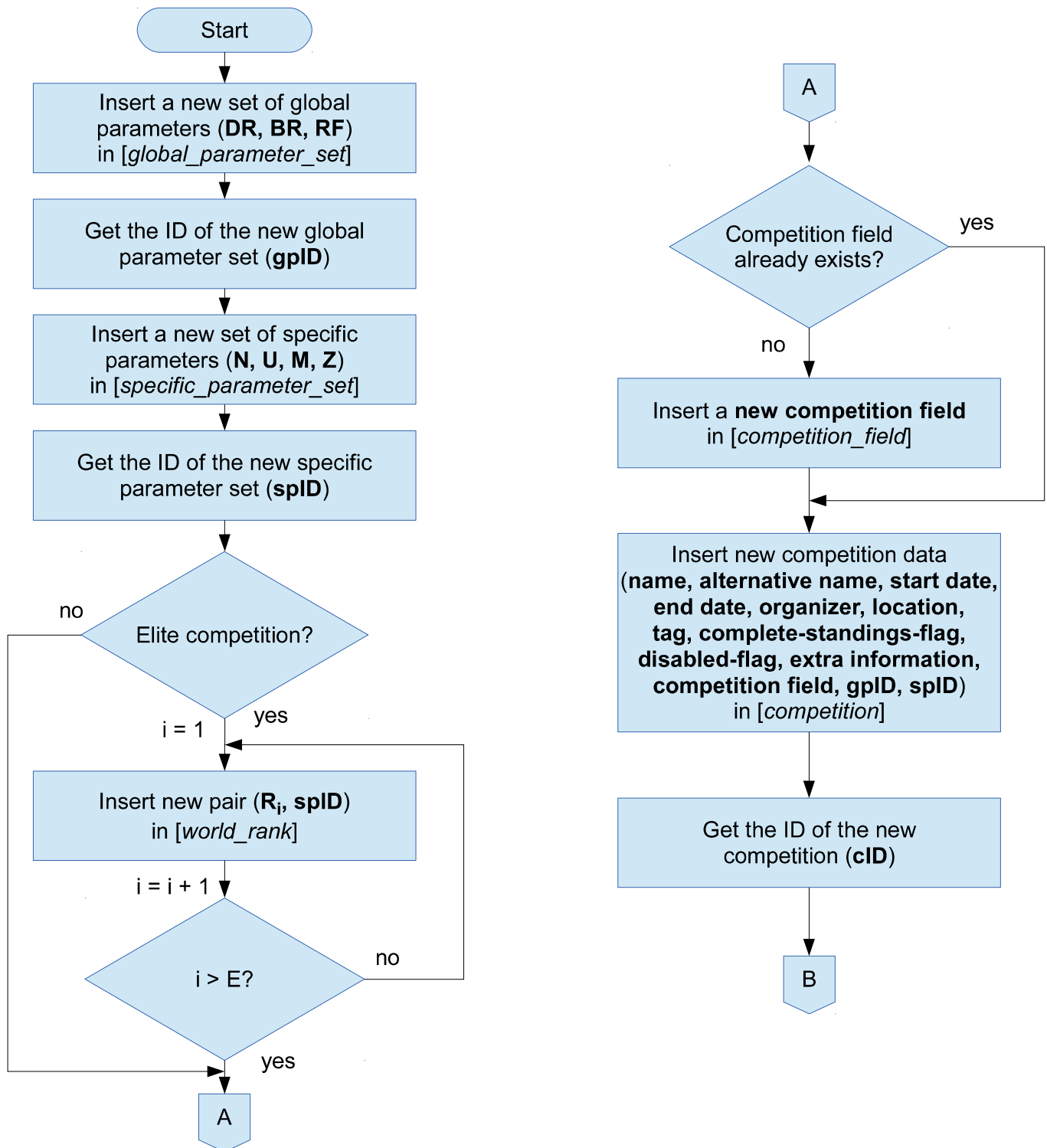


Figure 33a: Algorithm for inserting new competition data into the database

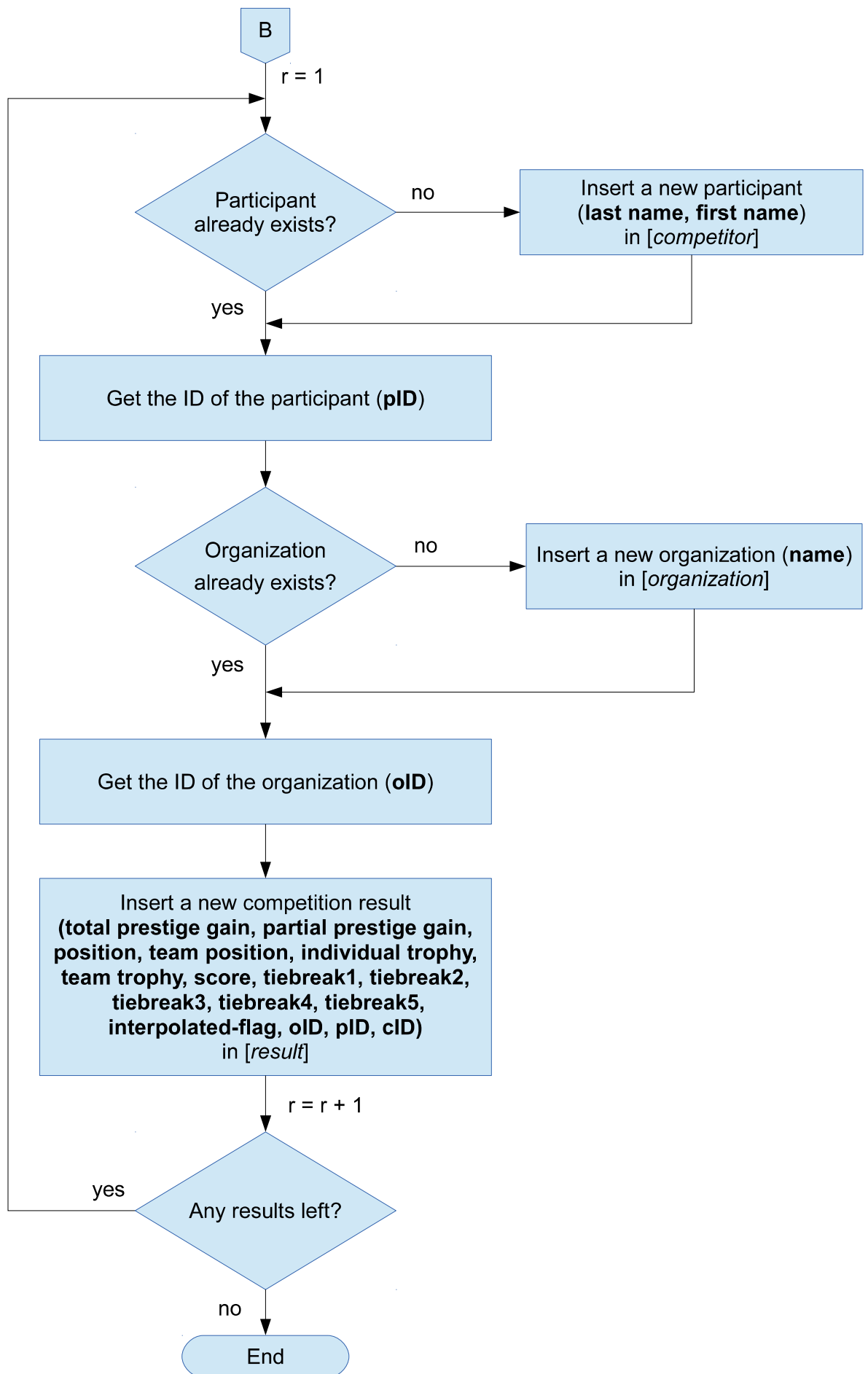


Figure 33b: Algorithm for inserting new competition data into the database

2. Data Retrieval

The most powerful feature of the ranking software is to create extremely flexible rankings. The algorithm for the data retrieval is quite straightforward (shown on Figure 34) but the strength lies in the generation of the SQL queries to the database.

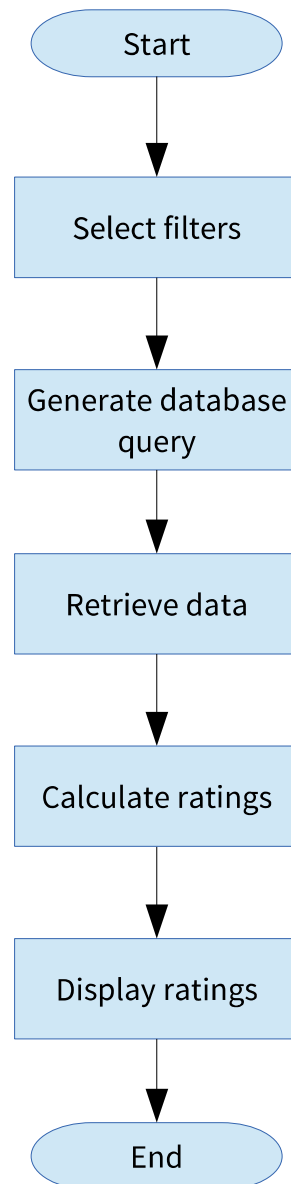


Figure 34: Algorithm for retrieving data from the database

After the ratings are generated they can also be exported in CSV, HTML or TXT format and used elsewhere according to the wishes of the user.

2.1 Filters

The user has the opportunity to apply diverse filters to the data. The user interface for that is shown on Figure 35 (the data is not real).

The data can be filtered by competition field, which makes possible to host all kind of competitions in one database and then just to filter the results. It is also possible to make rankings for only some competitors or only for some organizations. The filter “Competition” allows to narrow down the ranking to just one or more events and to see how many rating points every competitor has won from a certain competition. Also there is a filter to include only competitions during a certain period of time.

Competition field	Competitor	Organization	Competition	Time period
Chess Computer Mathematics Football Informatics Mathematics Physics Science Communication twall Volleyball	Anderson, Haidy Belev, Ivaylo Chen, Hu Ghanday, Bary Grossman, Anett Hatber, Pello Ivanova, Desi Kaiser, Annet Linde, Buske Loosey, Jif Mayer, Andrew Murphy, Jason Petrov, Stefan	Chess Club "Nayden Voin Chess Club "Tryavna-200 HSG Basketball The Lions e.V.	11th Open Velika Gorica 12. Int. Schach-Open Ne 21st International Chess 23rd EUROPEAN YOUTH Hotel Mundial Friday's Li Internationale Grazer Sta O POHAR SNP - FIDE OP Offene Spittaler Schachn X Calvia Amateur Open XXX Torneo Abierto Coli	First included date 31-Jul-09 15 Last included date 27-Aug-13 15 Advanced...
Total: 9	Total: 15	Total: 4	Total: 10	

Figure 35: Generating rankings

It should be noted that the advanced settings are not implemented in the software prototype because they are not of interest now. However the software is designed in a way to support their implementation at a next stage of development.

2.2 Design Patterns

The design patterns are reusable structures which have proven their reliability for solving certain tasks in software design. In the developed prototype the template method pattern is implemented. It is a design pattern that allows the definition of a group of similarly structured algorithms. These algorithms consist of multiple steps that can be interchangeable. Each algorithm goes through the same steps but provides a different implementation. The key feature is the ability to vary parts of the algorithm rather than replacing the algorithm entirely.

The template method design pattern is used in the generation of rankings. In the prototype only the standard static method of calculation is defined (which is enough in general) but in the future versions two more similar algorithms can be implemented. The first of them is the dynamic generation of the rankings that uses custom values for the global parameters and can be used for testing purposes. The other one is the raw calculation. It can recalculate all stored ratings in the database after a change of the mathematical model.

The overall structure of the algorithm is defined in an abstract class which defines the functionality for setting up the filters and the time devaluation function. The method for fetching the data from the database can be overridden by the different implementations of concrete classes which inherit from the abstract base class (Figure 36).

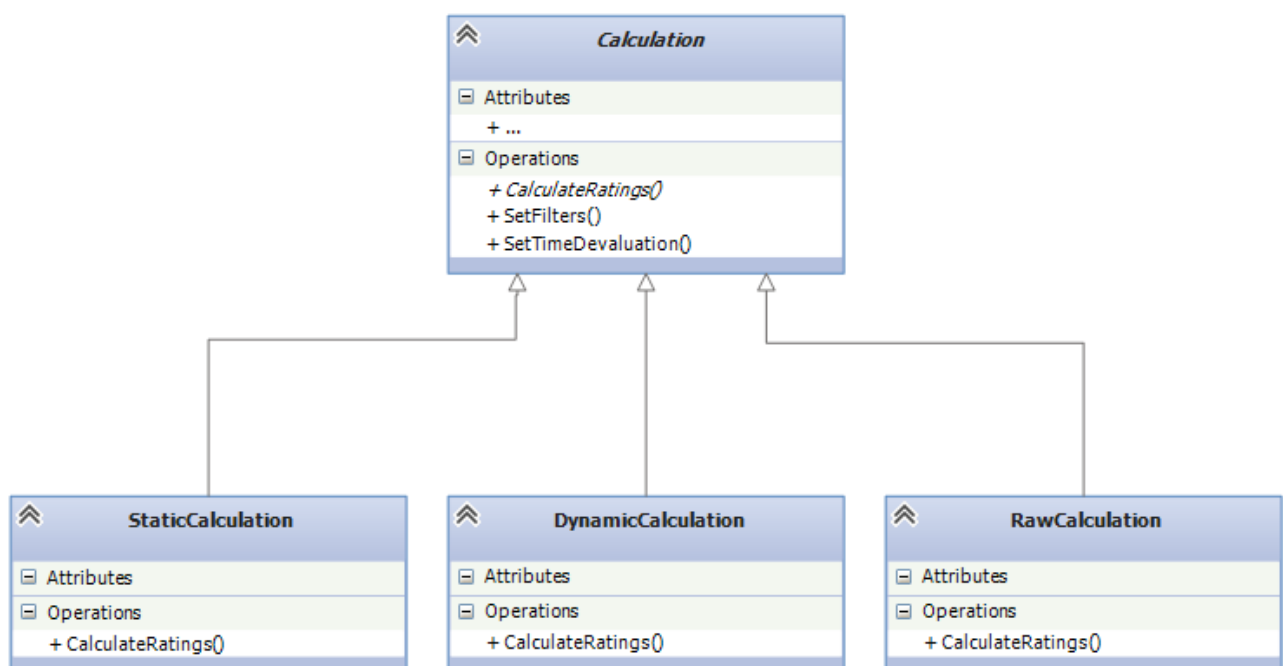


Figure 36: Using the template method design pattern

VII. Real Data Tests

In order to show the applicability of the new ranking system, **UnIdRaS** has been practically tested with real data in two areas. The areas have been chosen in a way to cover as much cases as possible with a minimum number of competitions. The first area relates to sport and is associated with only one competition field. The second area relates to science and multiple competition fields.

1. **twall**[®] Challenges

The **twall**[®] is an exergaming device used for reaction, coordination and endurance training. It exists since around 2005 and the games which can be played have competitive character. The first official competitions date back to 2008. Among the competitions, which have taken place, are two world championships (2009, 2010) and major competitions, called “**twall**[®] Challenge”, ever since (2011, 2012, 2013 under way). The **twall**[®] competitions have been chosen as suitable to create an **UnIdRaS** ranking because the **twall**[®] is a newborn discipline without any official governing body. This imposes a greater possibility of ambiguous cases. It is shown how such cases should be treated by a ranking administrator. Also it is shown how to deal with missing data.

1.1 Competitions

A variety of **twall**[®] competitions will be given here and it will be shown how to deal with ambiguities in them. All **twall**[®] competitions are classified under “Discipline Recognition” as “Sport E – Without any official governing body”.

1.1.1 **twall**[®] World Championship 2009

There are no standings available for this competition. However, some data can be collected from different online articles:

- The world championship took place in Mittweida.
- There was a qualification stage.
- In the finals the best 100 player from the qualifications have taken part.
- The first and the second in the competition are known.
- The winners got trophies.

Based on this information we make the choices how to set the parameters in **UnIdRaS**. The competition rank is class A – a world championship. This is the official status, no matter what other factors there might be.

The competition has no restrictions i.e. is open for everyone who wants to take part. This is different from the fact that one needed to qualify for the finals.

The number of participants is 100. We have no information about the format of the qualifications. Otherwise the number of participants in them could be added to the main number, or the qualifications treated as separate events.

The number of subunits is 1. For a world championship the participating countries should be counted as subunits. There is no information that participants from any other country than Germany took part. In this case the largest subunit will be set automatically by the software to 100 (the number of participants), if not done manually.

The performance in the competition was measured by the time for achieving a given task. The time of the participants can be converted to seconds and the result stored as a score. It should be entered with a minus sign to indicate that the score is of a less-is-better type.

1.1.2 **twall**® City Champion 2009

In this competition the winner became the one who played on most twalls during the three days of the “Tag der Sachsen” festival. No information is available about the number of the participants in the competition. That's why the number is set to just one. This automatically leads to 1 subunit and 1 as size of the largest subunit. When there is missing data, we assume a worst-case scenario, if no better assumption can be made.

The event took place in Mittweida but the festival was visited by 320 000 people from Saxony. Therefore the competition is considered regional.

1.1.3 **twall**® World Championship 2010

This was the first **twall**® competition with distinguished categories. Men, women and children played separately under different conditions. At the end there were three separate standings, in each of them the best three players got trophies. The three categories are treated as separate competitions in **UnIdRaS**. The men category is open to all but the women and children events have restrictions set – “Women” and “Under 16 years old” respectively.

Despite of the existence of a restriction for women in **UnIdRaS** the underlying value is equal to the one for the open (men) category. This is not true for age restricted events (e.g. the children category). One of the reasons is that children will grow up and then will compete in the higher categories. But women will not turn into men (and vice versa) and no one expects them to be and compete at the same level (in disciplines where there is a natural distinction between the two sexes).

1.1.4 **twall**® Challenge 2011

The Challenge was the biggest **twall**® competition for that year but had no officially assigned rank, showing if it was intended as a national or an international event. Furthermore the organization of the competition in that year made the players register their results by themselves. Although between 100 and 200 players have taken part in the Challenge, only 6 results have been made officially available. This is the number of participants to be entered in **UnIdRaS**.

Although at least one participant from a second country has taken part, there are no indications (e.g. a category “country” in the standings) to show that the event should be considered as international. Therefore, a national rank is assigned to this Challenge.

It is known that every 2 of the 6 participants come from a different city. Thus the number of subunits is 3 and the largest subunit has size of 2.

1.1.5 **twall**® Challenge 2012

In this competition again there were three different categories. This time the children category was replaced by a cities one, where mayors of different cities competed against each other. Being a mayor is a requirement and thus a restriction for participation in this category. However it is not seen as giving an advantage (being a mayor doesn't make the game easier, which is true for being a child). That is why the Restrictions are set to “unrestricted”.

In the **twall**® Challenge 2012 participants from many countries from three continents took part. This was the reason to classify the competition as intercontinental. However there was missing data regarding the countries of some participants. They were assigned to the host continent i.e. to the largest subunit.

1.2 Ranking Analysis

The available competition data from all major **twall**® competitions since the existence of this exergaming discipline has been entered in **UnIdRaS**. This allowed the generation of a ranking of the 585 participants in **twall**® competitions. The top **twall**® players can be seen on Figure 37. One of the major features of **UnIdRaS** is that it also makes inter-category comparisons. This is well-reasoned. While we are not able to compare direct performances between men and women (they play under different conditions), we can compare the prestige gained by them after participation in competitions.

Position	Name	Sex	Nationality	Rating
1	Player A	M	BUL	1646.481
2	Player B	M	AUT	698.137
3	Player C	M	GER	681.422
4	Player D	M	AUT	500.210
5	Player E	F	GER	388.800
6	Player F	M	GER	357.757
7	Player G	M	GER	331.516
8	Player H	M	GER	273.200
9	Player I	F	LTU	252.800
10	Player J	F	GER	248.386
11	Player K	M	GER	234.705
12	Player L	M	GER	218.560
13	Player M	M	GER	211.200
14	Player N	M	GER	182.133
15	Player O	F	GER	177.966
16	Player P	M	GER	156.114
17	Player Q	M	GER	137.000
18	Player R	M	AUT	136.600
19	Player S	F	GER	134.926
20	Player T	F	GER	126.400
21	Player U	M	BRA	109.600
22	Player V	M	GER	109.280
23	Player W	M	GER	107.184

*Figure 37: The top **twall**® players*

On the top position is the winner of the last three major **twall**® competitions (men categories).

Second is the runner-up from the **twall**® world championship 2010 (men) and on the third position is the winner of the **twall**® world championship in 2009 with a rating very close to the second participant. This might seem strange at first glance and that is why it needs explanation. Player B became second of 178 players and Player C – first of hundred. The

second placement is better but is fully compensated by the level of the competition. In the world championship in 2009 took part only participants from Germany, while in 2010 there have been participant from 8 countries (in the men category).

On forth place is the third in the twall® world championship 2010 (men), who ranks ahead of the winner of the the women section of the same championship. This is explainable by the fact that in the women section only 62 participants took part compared to 178 in the men section. Also Player D took a trophy which increases the value of the third place.

The sixth place goes to Player F, who is the runner-up in the world championship in 2009. We can compare this position to the 7th place of Player G, who is the runner-up in the Challenge in 2012. Although Player G achieved the second place in a competition with almost twice as many players than Player F, the Challenge in 2012 had no status of a world championship.

A special look should be given to the bottom of the rankings (Figure 38).

575	Player ZP	M	GER	2.884
576	Player ZQ	F	GER	2.873
577	Player ZR	M	GER	2.840
578	Player ZS	M	GER	2.300
579	Player ZT	M	GER	1.894
580	Player ZU	M	GER	1.840
581	Player ZV	F	GER	1.533
582	Player ZW	F	GER	1.420
583	Player ZX	M	GER	1.136
584	Player ZY	F	GER	0.947
585	Player ZZ	M	GER	0.350


Graphic 38: The bottom of the twall rankings

At the bottom we see Player ZZ who has become a twall® City Champion. Does he deserve the last position? Definitely not. Although this competition is with the lowest rank of all and no skills were required (the winner is the one who played on most twalls, which were situated in different locations), the champion deserves to be a few hundreds positions ahead. His last position is because of missing data.

Missing data is always a big disadvantage for the rankings of the participants. Well organized competitions should always provide freely accessible detailed data of the performance of the participants.

2. TUGab Index

The Technical University of Gabrovo uses a Prestige Gain Ranking System (PGRS) to rank the students by their achievements in national and international scientific competitions. The ranking system includes 40 competitions in the time period from September 2004 to present time. The data from these competitions has been entered in **UnIdRaS**. The first part of the ranking can be seen on Figure 39.



Position	Name	Sex	Nationality	Rating
1	Player A	M	BUL	4370.394
2	Player B	M	BUL	2621.807
3	Player C	M	BUL	1026.391
4	Player D	M	BUL	657.314
5	Player E	M	BUL	568.193
6	Player F	M	BUL	505.125
7	Player G	M	BUL	292.566
8	Player H	M	BUL	270.252
9	Player I	M	BUL	258.179
10	Player J	F	BUL	237.430
11	Player K	M	BUL	235.883
12	Player L	M	BUL	222.191
13	Player M	M	BUL	175.601
14	Player N	F	BUL	172.930
15	Player O	M	BUL	151.634
16	Player P	M	BUL	150.711
17	Player Q	F	BUL	105.184
18	Player R	F	BUL	98.280
19	Player S	M	BUL	78.416
20	Player T	M	BUL	70.499
21	Player U	M	BUL	51.190
22	Player V	M	BUL	50.688
23	Player W	M	BUL	50.688

Figure 39: A new TUGab Index calculated using **UnIdRaS**

The main differences compare to the PGRS come from the fact that **UnIdRaS** puts more weight on team competitions and in case of winning a team trophy (this is not accounted by the PGRS). Also the international competitions receive more weight in **UnIdRaS**. In PGRS the national and the international events are treated the same.

A discussion should be opened with the Technical University of Gabrovo for a replacement of the old ranking system with the new one. Further refinement of the parameters of **UnIdRaS** is also possible in order to meet the needs of the university.

Conclusion

A completely new rankings system has been developed within the present master thesis. It has the primary purpose to evaluate and measure prestige gained in competitions. This is a novelty approach to the competitive areas – viewing them as a way of gaining prestige, rather than the traditional viewpoint of demonstrating mastery.

The main contribution of the thesis consists in the original mathematical model that makes the ranking system unique. The ranking system is called **UnIdRaS** and claims to be universal and interdisciplinary. This is its main virtue compared to the existing ranking systems, which are usually specialized to fit their application area.

The present master thesis extends beyond the theoretical area. A prototype of a ranking software that implements this novel ranking system has been designed and developed. Its most powerful feature is the possibility to generate diverse rankings and to filter them in an extremely flexible way by combining multiple filters. This software makes the practical benefits of the ranking system immediately available to potential application areas.

Discussion

This is the first edition of the new ranking system and there is room for further enhancements which will be applied in the next versions of the system. Here are some thoughts about things in the system that can be further analyzed and improved.

In the mathematical model the Diversity Factor can be improved. Now it is calculated as a step function which depends either on the Homogeneity or on the number of subunits. It can be looked for a function that has both of them as parameters. It can be also analyzed whether the DF should depend on the number of participants too.

The Quality Premium should be also further analyzed. It seems that too much weight is put on winning a trophy. The trophy bonus should be probably decreased.

In terms of the software, it can be improved by including the dynamic and the raw methods of calculation of the ratings. This will be necessary if changes are made to the mathematical model in order to use the data which is already available in the database.

It will be good if the system offers detailed statistics about the competitions.

Area for further improvement is to check the names of the players and the organizations for possible mistakes or to offer the user to select them from a list. Also competitor profiles can be created.

Some other features can be developed like: versions for other operating systems (including an online-based version), user management, multiple database support, multiple language support.

The system will be further developed and efforts will be made to suggest it as an official ranking system for some organizations. Immediate candidates for this are the Technical University of Gabrovo, the chess club “Tryavna-2001”, as well as the **twall**®. The last one may become the first exergaming sport with an official world ranking list.

UnIdRaS already has a website – unidras.com and a logo which can be seen on Figure 40.

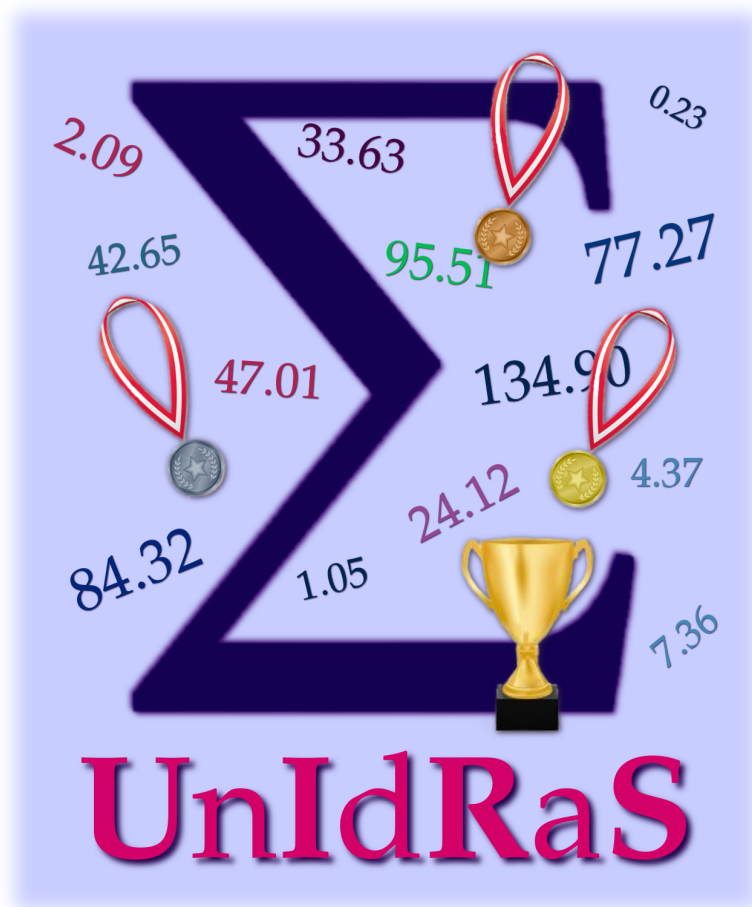


Figure 40: The official logo of **UnIdRaS**

References

- Barrow, Daniel; Drayer, Ian; Elliott, Peter; Gaut, Garren; Osting, Braxton (2013): Ranking rankings: an empirical comparison of the predictive power of sports ranking methods. In *Journal of Quantitative Analysis in Sports* 9 (2).
- Belev, Ivaylo (2013): Erstellung der Softwarearchitektur eines Ranking-Softwaresystems. A project in course "Architektur komplexer Softwaresysteme". Hochschule Mittweida - University of Applied Sciences, Mittweida, Germany.
- Bicknell, B.; Riley, T. (2012): The role of competitions in a mathematics programme. In *APEX: The New Zealand Journal of Gifted Education* 17 (1).
- Chartier, Timothy P.; Kreutzer, Erich; Langville, Amy N.; Pedings, Kathryn E. (2011): Sports Ranking with Nonuniform Weighting. In *Journal of Quantitative Analysis in Sports* 7 (3).
- Churcher, Clare (2012): Beginning Database Design: From Novice to Professional. 2nd New edition. Berkley: APress.
- Churilov, L.; Flitman, A. (2006): Towards fair ranking of Olympics achievements: the case of Sydney 2000. In *Computers & Operations Research* 33 (7), pp. 2057–2082.
- Csikszentmihalyi, Mihaly (1998): Flow. Das Geheimnis des Glücks. 6th ed. Stuttgart: Klett-Cotta.
- Deci, Edward L.; Ryan, Richard M. (1985): Intrinsic motivation and self-determination in human behavior. New York: Plenum (Perspectives in social psychology).
- Eccles, Jacquelynne S.; Barber, Bonnie L.; Stone, Margaret; Hunt, James (2003): Extracurricular Activities and Adolescent Development. In *Journal of Social Issues* 59 (4), pp. 865–889.
- Elliot, Andrew J. (1999): Approach and avoidance motivation and achievement goals. In *Educational Psychologist* 34 (3), pp. 169–189.
- González-Díaz, Julio; Hendrickx, Ruud; Lohmann, Edwin (2013): Paired comparisons analysis: an axiomatic approach to ranking methods. In *Social Choice and Welfare*.
- Herzberg, Frederick (1987): One more time: How do you motivate employees? In *Harvard Business Review* 65 (5), pp. 109–120.
- Langville, Amy N.; Meyer, C. D. (2012): Who's #1? The science of rating and ranking. Princeton [N.J.]: Princeton University Press.
- Lepper, Mark R.; Corpus, Jennifer Henderlong; Iyengar, Sheena S. (2005): Intrinsic and Extrinsic Motivational Orientations in the Classroom: Age Differences and Academic Correlates. In *Journal of Educational Psychology* 97 (2), pp. 184–196.
- Lins, Marcos P. Estellita; Gomes, Eliane G.; Soares de Mello, João Carlos C. B.; Soares de Mello, Adelino José R. (2003): Olympic ranking based on a zero sum gains DEA model. In *European Journal of Operational Research* 148 (2), pp. 312–322.
- Maslow, Abraham H. (1943): A Theory of Human Motivation. In *Psychological Review* 50 (4), pp. 370–396.

- Mitchell, Heather; Stewart, Mark F. (2007): A competitive index for international sport. In *Applied Economics* 39 (5), pp. 587–603.
- Ozturk, Mehmet A.; Debelak, Charles (2008): Affective Benefits from Academic Competitions for Middle School Gifted Students. In *Gifted Child Today* 31 (2), pp. 48–53.
- Posch, Torsten; Birken, Klaus; Gerdorf, Michael (2007): Basiswissen Softwarearchitektur. Verstehen, entwerfen, wiederverwenden. 2., überarbeitete und erweiterte Auflage Heidelberg: Dpunkt-Verl. (ISQI-Reihe).
- Richman, Erin L.; Shaffer, David R. (2000): If you let me play sports. In *Psychology of Women Quarterly* 24 (2), pp. 189–199.
- Riley, Tracy L. (2004): The extent, nature and effectiveness of planned approaches in New Zealand schools for providing for gifted and talented students. Report to the Ministry of Education. [Wellington, N.Z.]: Ministry of Education.
- Ryan, Richard M.; Deci, Edward L. (2000): Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. In *Contemporary Educational Psychology* 25 (1), pp. 54–67.
- Schumaker, Robert P.; Solieman, Osama K.; Chen, Hsinchun (2010): Sports Data Mining. Boston, MA: Springer US (26).
- Sitarz, Sebastian (2012): Mean value and volume-based sensitivity analysis for Olympic rankings. In *European Journal of Operational Research* 216 (1), pp. 232–238.
- Sitarz, Sebastian (2013): The medal points' incentive for rankings in sport. In *Applied Mathematics Letters* 26 (4), pp. 408–412.
- Soares de Mello, João Carlos Correia Baptista; Meza, Lidia Angulo; da Silva, Brenda Branco (2008): Some rankings for the Athens Olympic Games using DEA models with a constant input. In *Investigação Operacional* 28, pp. 77–89.
- Sorensen, Soren P. (2000): An overview of some methods for ranking sports teams. University of Tennessee. Knoxville.
- Souba, Wiley W. (2008): Rankings. In *Journal of Surgical Research* 148 (2), pp. 109–113.
- Stefani, Ray (2011): The Methodology of Officially Recognized International Sports Rating Systems. In *Journal of Quantitative Analysis in Sports* 7 (4).
- Til, Reinold H. (1978): Arrow's impossibility theorem. In *De Economist* 126 (1), pp. 84–115.
- Todorov, Todor; Belev, Ivaylo (2010): ТУ-Габрово – Състезателна статистика. Technical University of Gabrovo.
- Van Yperen, Nico W. (2006): A Novel Approach to Assessing Achievement Goals in the Context of the 2 x 2 Framework: Identifying Distinct Profiles of Individuals With Different Dominant Achievement Goals. In *Personality and Social Psychology Bulletin* 32 (11), pp. 1432–1445.
- Wigfield, Allan (1994): Expectancy-value theory of achievement motivation: A developmental perspective. In *Educational Psychology Review* 6 (1), pp. 49–78.

Declaration of Independent Work

I declare that I have independently written the work presented here, and I have not used any help other than from the stated sources and resources. I also declare that I have independently developed the software involved in this master thesis and I have not used any source code from others.

Mittweida, 30.08.2013

Ivaylo Belev